Escola d'Enginyeria de Telecomunicació i Aeroespacial de Castelldefels

UNIVERSITAT POLITÈCNICA DE CATALUNYA

FINAL DEGREE PROJECT

TÍTLE: Study of benefits Free Route Areas in Europe

DEGREE: Grau en Enginyeria de Sistemes Aeroespacials

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DATE: 20th June 2019

Títol: Estudi dels beneficis de les Free Route Areas a Europa

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Data: 20 de juny del 2019

Resum

La configuració actual del espai aeri està fragmentada, definida pels espais aeris nacionals segons les fronteres polítiques que afecten directament el medi ambient, els avions i els costos de la navegació aèria.

L'espai aeri del futur a Europa ha de fer front als nous reptes per donar suport a l'augment del trànsit aeri en una nova configuració d'espai aeri. L'espai aeri Free Route (FRA) és un nou concepte per reestructurar els sectors i les aerovies que dóna més flexibilitat als usuaris de l'espai aeri per crear rutes millors i més eficients. A l'espai aeri Free Route, els usuaris poden planificar una ruta entre un punt d'entrada definit i un punt de sortida definit sense utilitzar la xarxa ATS, sempre subjecte al control de trànsit aeri.

Aquest projecte té com a objectiu estudiar els beneficis de les àrees Free Route en dos escenaris. Un existent i un creat. El primer escenari estudia els avantatges de les àrees Free Rote del nord d'Europa que porten actius desde 2015. El segon escenari estudia l'impacte d'un espai aeri Free Route a gran escala.

Aquest projecte utilitza l'eina NEST, d'Eurocontrol, per simular el trànsit amb i sense FRA. A més, es tractarà el pronòstic futur per donar suport a l'avaluació a llarg termini del concepte de FRA.

L'estructura d'aquest projecte s'inicia amb una breu revisió teòrica del concepte d'espai aeri Free Route i del primer escenari avaluat. A continuació, aquest projecte inclou tots els passos de disseny i el procés d'avaluació per obtenir els paràmetres avaluats. Finalment, es presenten els resultats de NEFRA i EUROFRA.

En general, els resultats d'aquest projecte mostren que els usuaris de l'espai aeri es beneficien enormement de la implementació d'àrees Free Route. Les companyies aèries poden estalviar diners i combustible viatjant menys distància mentre es manté la seguretat. A més, el medi ambient es beneficia en termes reducció d'emissions d'efecte hivernacle. Amb la implantació de l'EUROFRA, es poden estalviar aproximadament 5 mil tones de CO_2 al dia.

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Overview

The current airspace configuration is fragmented, defined by national airspaces according political borders that affects directly to the environment, aircraft and air navigation service costs.

The future airspace of Europe is addressing new challenges to support the increase of the air traffic in a new airspace configuration. The free route airspace (FRA) is a new concept to restructure the sectors and airways that gives more flexibility to airspace users to create better and more efficient routes. In Free Route areas users may plan a route between a defined entry point and a defined exit point without reference to ATS network, always subject to air traffic control.

This project aims to study the benefits of free route areas in two scenarios. One existing and a created one. The first scenario studies the advantages in the North European Free Route area which were implemented since 2015. The second scenario studies the impact of a free route airspace in a large scale.

This project uses the NEST tool, from Eurocontrol, to simulate the traffic with and without FRA. Also, will be addressed future prognosis to support the long-term evaluation of the FRA concept.

The structure of this project starts with a brief theory review of the Free Route Airspace concept and the first scenario evaluated. Then this project includes all the design steps and evaluation process in order to obtain the metrics evaluated. Finally, results of NEFRA and EUROFRA are presented.

In general, the results of this project show that airspace users are greatly benefited from the implementation of Free Route Areas. Airlines can save money and fuel travelling shorter distance while safety is maintained. Also, environment is benefited in terms of greenhouse emissions. With the implementation of EUROFRA, approximately 5 thousand tons of CO_2 can be saved per day.

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ABBREVIATIONS

ACC	Area Control Centre
AIP	Aeronautical Information Publication
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
CANSO	Civil Air Navigation Services Organisation
CFMU	Central Flow Management Unit
DDR	Demand Data Repository
DK/SE FAB	Denmark Sweden Functional Airspace Block
ECAC	European Civil Aviation Conference
ENR	En-Route
EUROFRA	European Fee Route Airspace
FIPS	Flight Increase Process Simulator
FIR	Flight Information Region
FL	Flight Level
FRA	Free Route Airspace
HDIF	Horizontal Different Interacting Flows
HEFRA	Hungarian Free Route Airspace
IATA	International Air Transport Association
IFR	Instrumental Flight Rules
NEFAB	North European Functional Airspace Block
NEFRA	North European Free Route Airspace
NM	Nautical Miles
RVSM	Reduced Vertical Separation Minimum
SDIF	Speed Different Interacting Flows
SESAR	Single European Sky ATM Research
SID	Standard Instrumental Departure
STAR	Standard Terminal Arrival Route
VDIF	Vertical Different Interacting Flows

INTRODUCTION

The European air traffic Management system (ATM) is looking for solutions to support the increase of the air traffic by the implementation of a new airspace concept. Free Route Areas (FRA) is a concept developed by Eurocontrol that supports this challenge allowing users to plan a route between a defined entry point and a defined exit point without reference to ATS network. This new structure of airspace creates better and more efficient routes while maintaining the levels of safety.

The objective of this Project is to study the benefits of Free Route Areas in EUROPE evaluating parameters such as flight distance or complexity in different scenarios.

This Project is divided in five chapters. The first chapter tries to give a brief theory review of the Free Route Airspace concept and the first scenario evaluated. This section is developed in order to better understand following chapters.

Second chapter presents all the necessary steps before obtaining the results and the corresponding conclusions of the Free Route Airspace. It describes all the steps done during the simulations and presents all the parameters evaluated in detail.

Third chapter presents all the results from simulation of this project corresponding to the first scenario where NEFRA is evaluated. This part is considered the most important from this project because conclusions of Free Route areas can be obtained.

Fourth chapter presents all the results from simulation corresponding to the second scenario where EUROFRA is evaluated. This part tries to give a measure the advantages and disadvantages that a Free Route Area with the size of Europe.

Last chapter exposes the conclusions obtained from the project.

CHAPTER 1. FREE ROUTE AIRSPACE

This chapter presents the main concepts and definition related to Free Route Airspace. Pretends to settle a background with the objective to understand next chapters developed through the project.

1.1. Why the need of free route airspace?

Since 1993 through the liberalisation of the European Union aviation market traffic has increased by 54%. Travel is much more accessible and affordable and has stimulated growth in air services [1]. Volume of air traffic is growing steadily every year. In 2018, IFR movements continued to grow strongly (+3.8% versus 2017), making last year a new record year in terms of traffic volumes. In 2020 EUROCONTROL forecast 3.0% growth to reach 11.65 million flights which implies in more delays and the need of continuous improvement of European ATM [2].

Causes of delays are diverse, reduction of capacity is one of them. Also, delays are caused by the fact that air traffic control in Europe is fragmented and as a result, inefficient. It is structured around national boundaries and flights are unable to take direct routes. Compared with USA, Europe has 38 air navigation service providers (ANSP) and manages 30.000 flights daily. The USA manage 60.000 flights daily with only one ANSP.

With this situation the “do nothing scenario” will result on flight cancellation and missed connections, CO_2 emissions increase, 11% airlines demand will not be accommodated, the jeopardize of the airlines productivity gains and a negative impact on safety [3].

One way to increase capacity and efficiency of airspace and to reduce the environmental impact is flying directly between two points. This can be achieved with free route airspace.

1.2. Free route definition

Free route airspace (FRA) is defined in [4] as “a specified airspace within which users may freely plan a route between a defined entry point and a defined exit point, with the possibility to route via intermediate (published or unpublished) waypoints, without reference to the ATS route network, subject to airspace availability. Within this airspace, flights remain subject to air traffic control”.

The goal of this concept of airspace is removing the constrains imposed by the fixed airways structure by an airspace which users can flight their preferred trajectories maintaining the levels of safety. FRA optimises the use of airspace allowing more direct routes.

Currently, the defined area is located at the highest levels of airspace, often in cruise, above airspace with conventional ATS routes, (see Fig. 1.1) [5].

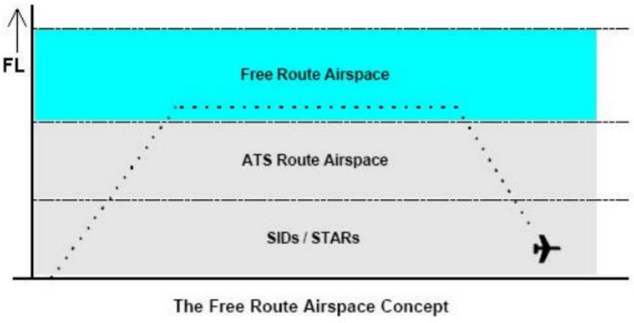


Fig. 1.1 Position of FRA Area

The next figure (Fig. 1.2) presents the basic concept of Free Route Airspace. It can be seen that FRA enables aircraft to fly over an area on the shortest possible route, in a straight line between entry and exit points. This results in advantageous effects for aircraft operators, passengers and the environment while maintaining or reducing the controller's workload.

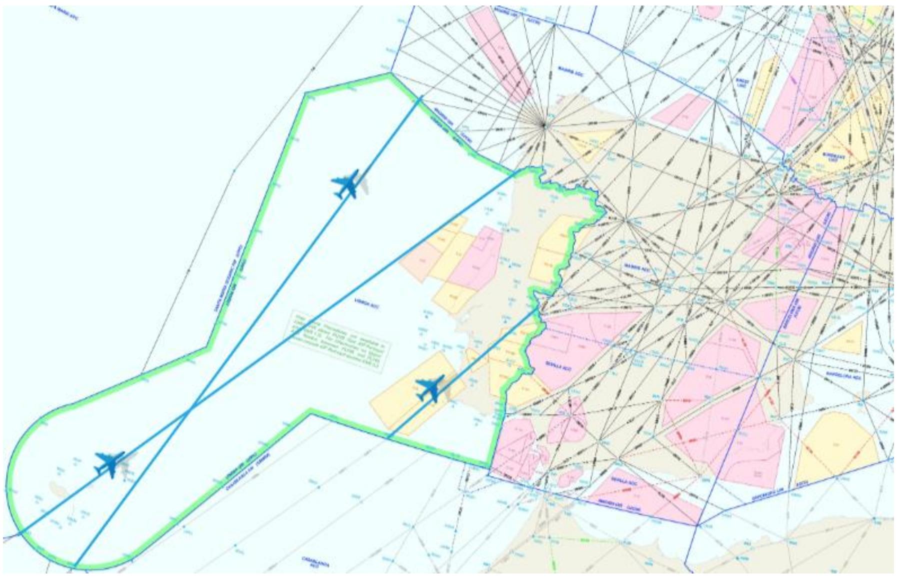


Fig. 1.2 FRA concept

1.2.1. FRA significant points

Significant points in Free Route airspace are published in national AIPs ENR 4.1 and 4.4 with a clear reference to the FRA and the relevance of the point. Waypoint locations take into account navigation aids, operational requirements and traffic flows.

Table 1.1 shows the FRA relevance of the significant points. They shall be indicated with the corresponding letter published within brackets.

Table 1.1 FRA significant points

FRA significant point	Definition
Entry (E)	FRA point on the horizontal boundary where entry is allowed
Exit (X)	FRA point on the horizontal boundary where exit is allowed
Intermediate(I)	FRA published or unpublished point, defined by geographical coordinates where operations are allowed.
Arrival (A)	FRA operations are allowed for arriving traffic to specific aerodromes. Linked to STARs (standard arrivals)
Departure (D)	FRA operations are allowed for departing traffic from specific aerodromes. Linked to SID (Standard instrumental departures)

Combinations of letters can be published when a point have different functions. For example (EX) both functions, entry and exit are permitted. Fig. 1.3 shows an example of the combination of FRA significant points and their location in the North European Free Route Airspace (NEFRA).

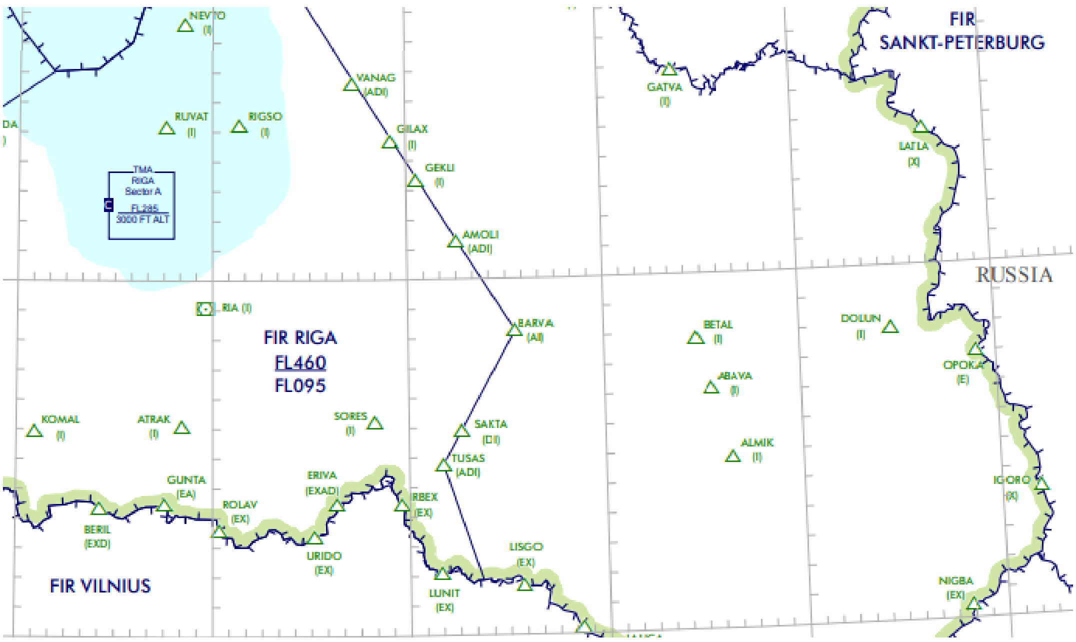


Fig. 1.3 Example of FRA points [6]

1.3. Implementation

Europe is the first region in the world to have implemented the full free route airspace concept. Although, in other regions of the world such as North America or Australia some flight efficiency initiatives have been developing.

Free route airspace deployment has been increasingly becoming more usual in Europe. It was initiated by EUROCONTROL in 2008 and was included in the Flight Efficiency Plan developed cooperatively between IATA, CANSO and EUROCONTROL [4]. However, nowadays most of the European airspace is characterised by a fixed flight network.

On 2011 Lisbon FIR became the first ANSP in Europe enabling to fly in a free route region. Years later, on 5th February 2015, Hungaro Control abolished for first time its air traffic services network in HEFRA (Hungarian Free Route Airspace). By the second half of 2016, multiple service providers like the Serbian, the Croatian, the Austrian and the Romanian joined the Hungarian example with the Free Route programme [7].

By the end of 2017, 51 ACCs had implemented Free Route Airspace operations. Some of these ACCs have limited the use of Free Route Areas to low traffic situations including some time constrains (night and/or weekends only) or space (defined sectors) restrictions. This exceeds the target of 35 ACCs set by the Network Manager Performance plan [8].

The cooperation between the Network Manager, the ANSP, military partners and airspace users shall result on a full FRA implementation in Europe by 2024 (see Fig. 1.4) [8].

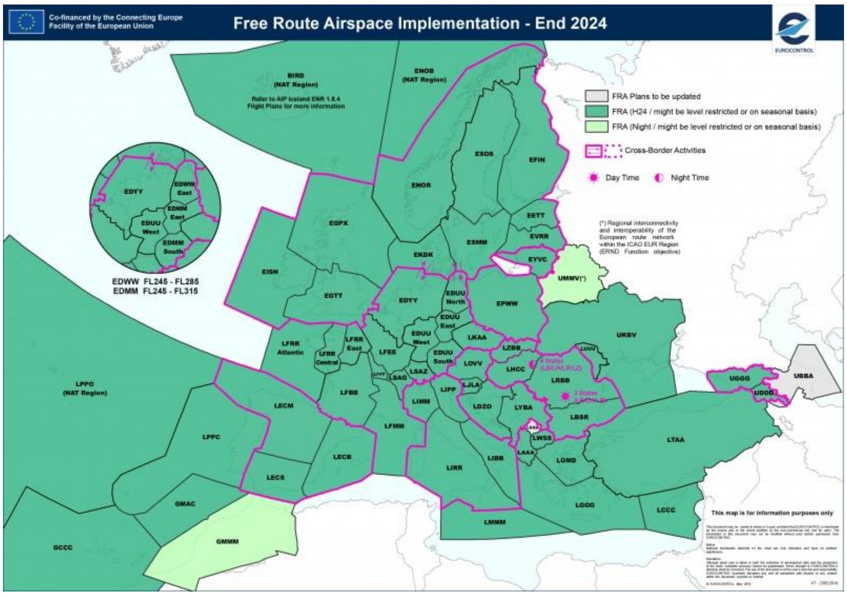


Fig. 1.4 Free Route Airspace implementation plan for 2024 [4]

Additionally, cross border implementation which remove national borders is available in many parts of Europe, for example SAXFRA (Austria / Slovenia), SEENFRA (Romania / Hungary / Bulgaria), SEAFRA (Belgrade / Zagreb ACCs), and NEFRA (Estonia / Latvia / Finland / Sweden / Denmark / Norway).

1.4. Implementation of Free Route Airspace in Northern Europe

In 2013 Ministers of Transport on six North European states, Denmark, Sweden, Norway, Finland, Latvia and Estonia decided to implement Free Route Airspace in the airspace controlled by their national ANSP. They called it NEFRA. This project evaluates this scenario in order to study the benefits of a Free Route Airspace.

The NEFRA programme was established on 11th March 2013 as a cross-border project. NEFRA, due to the geographical location and his cross-border nature, attached special attention by Europe. NEFRA is used as a bridge to the East for flights between Europe and Asia, and to the West to connect North European Flights with North America.

NEFRA (see Fig. 1.5) project was finished in the 12th November 2015, 7 years before the mandatory deadline established by the regulation when the six states of two Functional Airspace Blocks – Denmark, Sweden (DK/SE FAB), and Norway, Finland, Estonia and Latvia (NEFAB), signed a declaration of commitment in airspace development, committing themselves to undertake necessary actions to ensure implementation of the FRA concept above FL 285 in the entire airspace of NEFAB and DK/SE FAB [6].

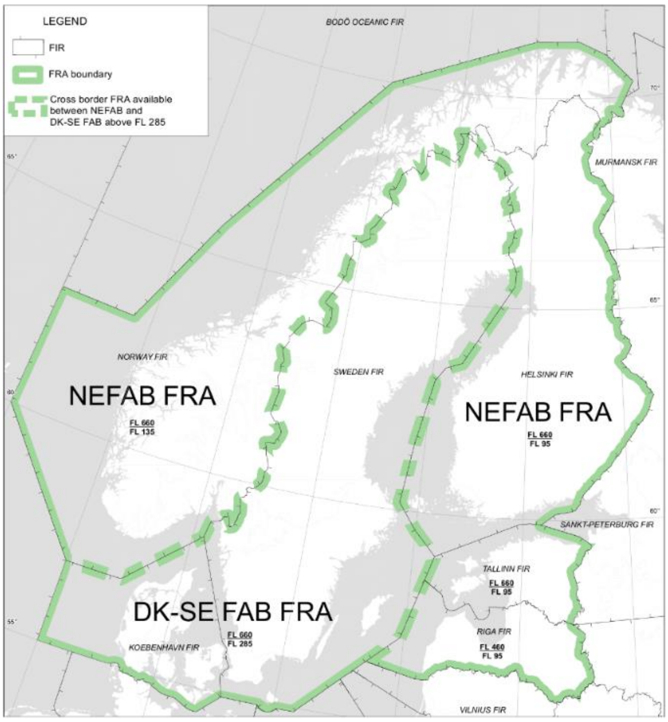


Fig. 1.5 NEFRA as the union of NEFAB and DK-SE FAB [6]

CHAPTER 2. SIMULATIONS

This chapter presents all the necessary steps before obtaining the results and the corresponding conclusions of the Free Route Airspace. It describes all the steps done during the simulations and presents all the parameters evaluated.

2.1. Simulation tool

In order to study the benefits of free route airspace, it’s necessary to do a process of simulation where free route trajectories are processed. This process will be performed using NEST (Network Strategic Tool).

This tool is used by the Eurocontrol Network Manager and national Air Navigation Service Providers (ANSPs) for airspace structure design and development, for capacity planning and post operations analysis, for strategic traffic flow organisation, for scenario preparation for fast and real-time simulation, and for ad-hoc studies at local and network level [9].

All the data necessary to run the software, including traffic demand, route network, forecast and traffic can be downloaded from de Demand Data Repository (DDR) web site [10].

2.2. Traffic samples

This project takes into account the last filed flight plan from the airlines, also known as “initial trajectory” or “m1” files which is available in the Demand Data Repository from Eurocontrol [10]. These files contain 4D planed trajectories crossing the European airspace and the aircraft type. Selected trajectories are specifically the historical trajectories from the second week of October from the years 2012, 2018 and 2024. For each day, 24 traffic hours have been considered. In total, 14 days are extracted.

The reason for selecting these dates was to consider nominal conditions; this is, without strikes by air traffic controllers, adverse meteorological conditions, holiday periods or other phenomena that affect air traffic.

Year 2012 traffic sample extraction considers data from AIRAC cycles before the implementation of NEFRA. On the contrary, during 2018 this free route area has been fully implemented. Notice that opposite to some free route areas, for example HEFRA where conventional airways are not available, in NEFRA they are still available, so, there are airlines that may choose flight in a conventional way.

Traffic from 2024 has been obtained doing a traffic forecast simulation, specifying the FIPS (Flight Increase Process Simulator) traffic increase options. FIPS is an algorithm that uses a current traffic sample to convert traffic forecasts into future traffic samples. Flights are added and removed randomly to maintain existing traffic patterns while respecting system constraints such as airport capacities and curfews. FIPS works with traffic forecasts (STATFOR) expressed as percentage increases at the OD (origin-destination) zone level [11] (see Fig. 2.1).

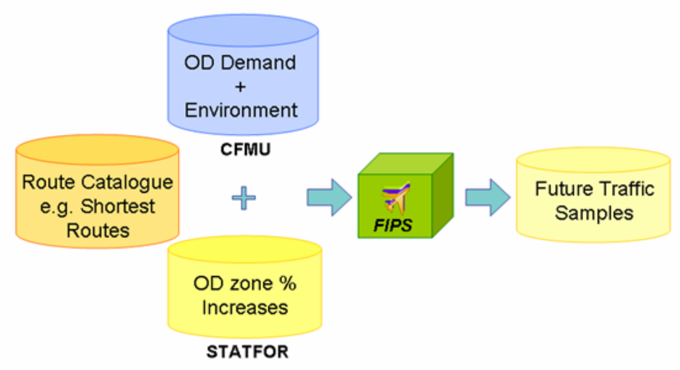


Fig. 2.1 Traffic forecast simulation [11]

STATFOR forecasts indicate the percentage increase for airport pairs giving a comprehensive picture of anticipated air traffic development in Europe. In this case, 2024 traffic sample has been generated from 2018 traffic and a traffic increment between 14% and 20% has been set depending on the day. Table 2.1 shows the number of flights in each of the 21 traffic samples selected. Cells marked in red and yellow shows the busiest days.

Table 2.1 Number of flights in each traffic sample

	2012	**2018**	**2024**
Monday	29,794	34,647	41,261
Tuesday	29,052	33,431	42,804
Wednesday	29,909	33,886	41,245
Thursday	30,502	34,790	41,826
Friday	30,405	34,917	43,041
Saturday	24,295	29,541	43,306
Sunday	26,601	32,114	37,505

Notice that Thursday and Friday were the busiest days in terms of air traffic during this week in 2012 and 2018. Maximum volume of flights reaches almost 35 thousand flights in 2018. On the contrary, Saturday the amount of traffic is minimum for both years mentioned. The 2024 traffic samples obtained with the forecast says that maximum values of traffic are found in Friday and Saturday while minimum volumes of traffic are found on Monday.

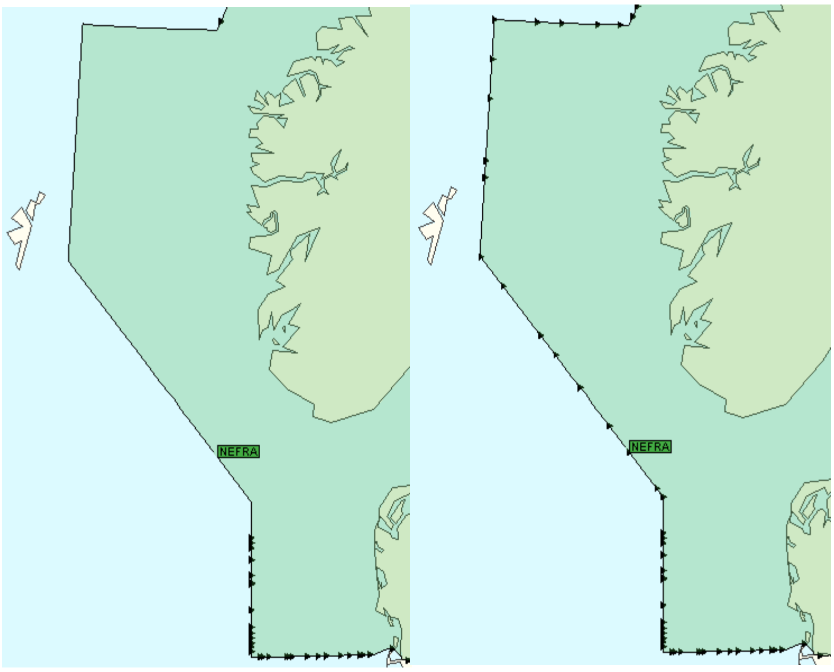
2.3. Scenarios evaluated

2.3.1. NEFRA

This first scenario considers the region of the Northern Europe Free Route Airspace, known as NEFRA, presented in section 1.4. The vertical limits are compressed between FL285 and FL660. Fig. 2.2 shows how it is presented in NEST. Dots show all the fixes presents in this free route area. It includes intermediate points, entry/exit and arrival/departure points.

Fig. 2.2 NEFRA

The file containing the shape of this region has been downloaded from DDR and will be the zone where free route will be simulated. Consist in a text file containing the latitude and longitude points that define the limits of the area. First of all, was completed with the missing entry / exit points. Fig. 2.3 a) shows the original data extracted from DDR while Fig. 2.3 b) shows the result of completing missing points in the border of NEFRA. This process was possible by consulting the aid of the corresponding ANSP (Norway, Finland, Sweden, Estonia, Latvia, Denmark) [6], [12]–[16].



a) Original DDR *b) Completed*

Fig. 2.3 Before and after of NEFRA entry points

All 2012 traffic samples are simulated with the real sectorization corresponding to the 18th November 2012 which is the closest day with this information available in DDR. In a similar way, 2018 traffic samples use the sectorization corresponding with 31th January 2019. This is also the sectorization used with the 2014 traffic samples.

In this scenario, all the flights crossing NEFRA have been considered with some exceptions. Flights that initially crossed NEFRA and after doing the simulation they didn't cross, have been discarded. The number of flights discarded are minimum, around the 0.03%, and don't affect overall results.

2.3.2. EUROFRA

This second scenario considers the region of EUROFRA, initially presented in reference [17]. The reason of selecting this scenario is to evaluate the extreme future implementation of a Free Route Area. EUROFRA is defined as a unique airspace block corresponding to the European Civil Aviation Conference (ECAC) area and joins all the ACCs in Europe. The vertical limits are compressed between FL250 and FL660. Fig 2.4 shows how it is presented in NEST.

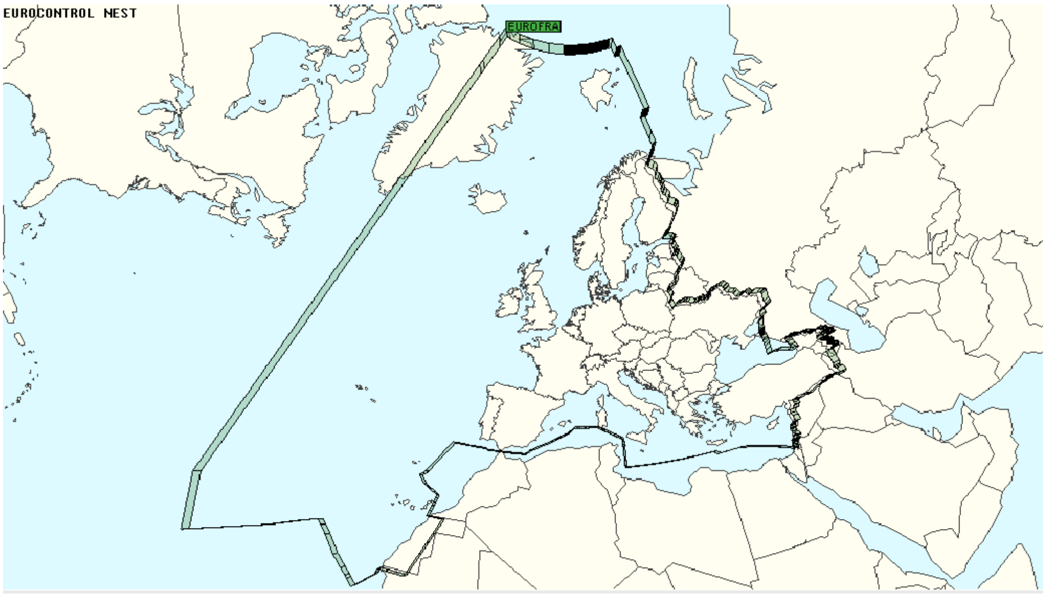


Fig. 2.4 EUROFRA

As in the last scenario evaluated, some points were defined. On the west part or EUROFRA, as current airspace is already defined, Free Route Airspace entry and exit points are directly obtained from DDR. In the regions where Free Route Airspace is not available some points need to be created. In the case of arrival/departure points, they should be connected with the corresponding SID and STAR.

For simplicity reasons, the sectorization used in this scenario is the same as in NEFRA but considering all European ACCs. Airspace sectorization in this ambitious scenario is a challenging problem because sectors must be modelled according to the traffic flow and demand.

All the flights that initially and after simulating crossed EUROFRA have been considered.

2.4. Simulation process

The process for the traffic simulation is summarized in Fig. 2.5. Once obtained the traffic samples and the network environment, it is necessary to do the required steps to prepare the scenario which includes adding waypoints or preparing the necessary files.

The method used to simulate the scenarios is called “Free route processing” which calculates 2D straight trajectories between entry and exit points. These 2D trajectories are then converted to 4D trajectories with the method “Profile” adding time and flight level to each route point.

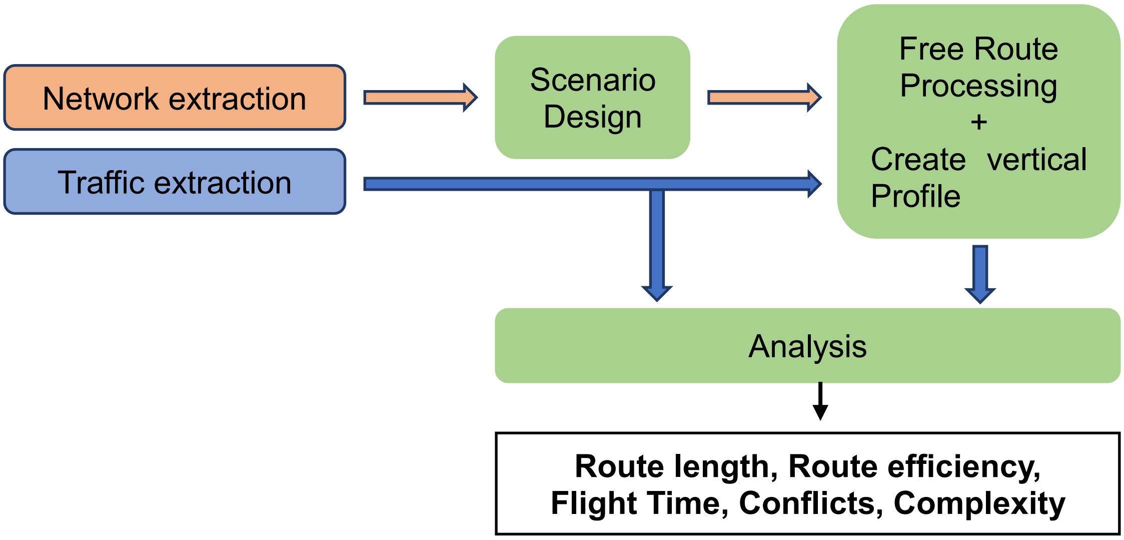
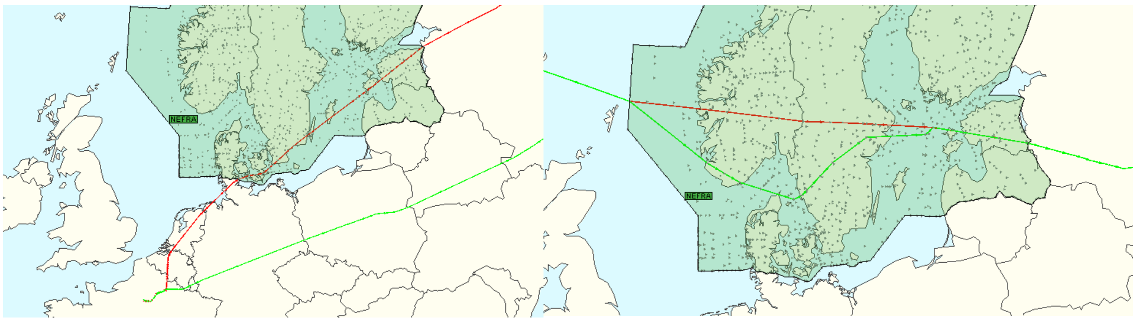


Fig. 2.5 Simulation Process

Other available NEST methods such as “Assignment” or “simulate trajectory” have been discarded because the results have not been as expected. The first one simulates the entire trajectories (see Fig. 2.6 a)); this makes the initial (red) and the simulated route (green) differ too much and conclusions about free route airspace are difficult to be taken. The second method (see Fig. 2.6 b)) calculates trajectories that do not approach to the theoretical free route trajectories for some flights.

After simulation, with the two files containing the simulated and initial trajectories, the appropriate functions have been used to obtain the parameters to be evaluated.



a) Assignment b) Simulate trajectory

Fig. 2.6 Trajectory simulations methods discarded

2.5. Evaluated parameters

With the objective of studying the benefits of Free Route Airspace, route length, route efficiency, flight time, number of conflicts and complexity have been evaluated after doing the simulations.

From commercial aircraft operator's point of view, their main objective is to obtain the highest number of benefits always doing a safe operation. To make this possible they have to burn less fuel because fuel contributes as airlines largest fraction of operating costs (26.5%) [18]. Consequently, airlines would like to fly the shortest route in the minimum period of time considering the best weather conditions.

Moreover, reducing the fuel consumption implies a reduction in the effect that flights have on the environment by reducing CO_2 emissions. In fact, this is one of SESAR performance ambitions for 2035 which objective is to reduce emissions in a 10% [19].

From ANSP point of view, the number of conflicts or separation losses as well as the airspace complexity will be studied assessing if free route airspace compromises safety. This is another SESAR performance ambition for 2035 which aims to improve it by a factor of 10 [19].

2.5.1. Saved Distance

Route Length provides a broad analysis of the route extensions and aims at assessing benefits in terms of saved distance. This parameter will be the difference between the actual route length and the simulated one in absolute values.

Higher values of saved distance will result in economic benefits for airspace users and a reduction in those engine exhaust pollutants that cause illness and premature mortality associated with fuel consumption [20].

Also, relative saved distance will be measured by dividing the total saved distance by the total route length.

2.5.2. Route efficiency

In En-route airspace, aircraft often fly on structured airway routes with a constrained number of flight levels and cruising speeds available. These constraints, added to structural limitations, such as national borders or opening schemes, are often imposed to manage the complexity of the air traffic control process for the human controllers [21].

Free route approximates the ideal air transportation system, where all aircraft could fly their optimal trajectories between airports. Route efficiency, presented in [11] takes this idea of measuring the optimal trajectories. Not considering wind conditions, the most efficient route (100%) will be which follows a direct route and can be computed as:

$$\text{Route efficiency (\%)} = \frac{\text{Direct Route (NM)}}{\text{Route length (NM)}} \cdot 100 \tag{2.1}$$

Route efficiency will be presented in percentage; higher values will correspond to better route efficiencies.

2.5.3. Saved time

In the same way, another parameter evaluated will be flight time measured by each flight trajectory inside the airspace presented in saved hours.

Higher absolute values of saved time will result in higher benefits for airspace users. Also, relative saved time will be measured by dividing the total saved time by the initial flight time.

2.5.4. Aircraft conflicts

Expecting inevitably an increase of traffic growth, the ambition is to maintain or reduce the level of safety associated with the ATM, for this reason aircraft conflicts are analysed.

An aircraft conflict can be defined as an event in which two or more aircraft experience a loss of minimum separation. In other words, the distance between aircraft violates a criterion defining what is considered undesirable. One example criterion is a minimum of 5 NM of horizontal distance between aircraft or at least 1000 ft of vertical separation (the current en-route separation standard). The result is a protected zone or volume of airspace surrounding each aircraft that should not be infringed upon by another vehicle. The protected zone could also be defined as a much smaller region (e.g., a sphere 500 ft in diameter) in the case of tactical collision alerting systems, or even in terms of parameters other than distance (e.g., time) [22].

Conflicts will be calculated for initial and free route traffic crossing and flying inside NEFRA using the separations distances given above (5NM of horizontal and 1000 ft or RVSM in vertical).

As aircraft may not always take off on time then some uncertainties will be added on each run. Ten fast-time simulations have been done. First run was set to the actual departure time, the following, departure time was distributed along a Gaussian function with an average of 120 seconds and standard deviation of 120 seconds.

In each run, conflicts are calculated in intervals of ten seconds.

The final safety indicator is computed as the number of separation losses averaged for all runs. The durations of the separation loss and the type of conflicts will help to determine the controller workload. Another safety indicator will be the duration of the separation losses and the conflicts type.

2.5.5. Airspace Complexity

This last parameter evaluated in this project takes into account the aspects that contribute to controller workload which are briefly illustrated in Fig. 2.7. The main factors are [23]:

- ATC procedures-related complexity: Mostly internal factors of the ANSP. Includes two components, one related with ATC procedures, route structure, airspace organization… and the other related with the concept of operation and technology.

- Traffic characteristics: External factor of the ANSP related with the type, interaction and concentration of the traffic.

- External factors: includes the nature or structure of the airspace through which traffic is flying, location of major airports and crossing flows, difference on aircraft speeds due to the aircraft type or the presence of military areas.

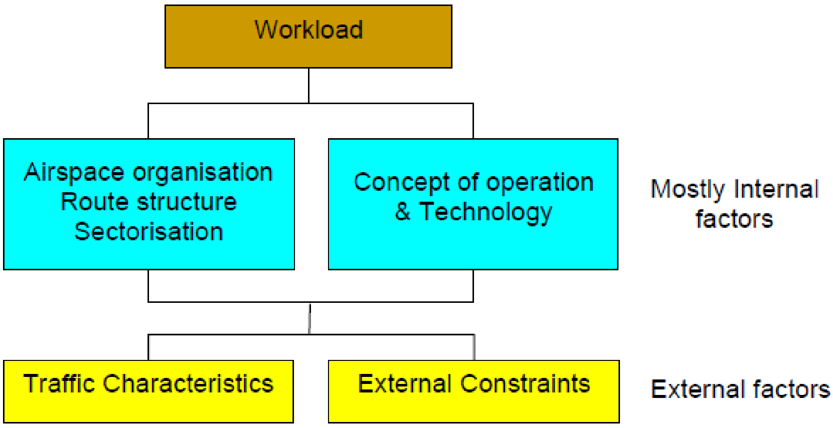


Fig. 2.7 Factors involving controller’s workload [23]

Complexity indicators give a measure of the external factors impact on the controller workload and their task level of difficulty without considering their internal procedures and methods. Complexity reflects the traffic characteristics and the external constraints, independently from the route network and sector design.

There is no universal definition applicable to ATM, so, this project uses the Eurocontrol complexity score [23] which principal indicators are summarized in Table 2.2.

Table 2.2 Complexity indicators

Complexity Dimension	Indicator	Description
Traffic density	Adjusted density	Potential number of interactions between aircraft in a given volume of airspace.
Traffic in evolution	Potential vertical interactions (VDIF)	Potential interactions between climbing, cruising and descending aircraft.
Flow structure	Potential horizontal interactions (HDIF)	Provides a measure of the potential interactions based on the aircraft headings.
Traffic mix	Potential speed interactions (SDIF)	Assesses the potential interactions based on the differences of aircraft speeds.

The concept of “interaction” occurs when two aircraft are present in a 3D cell of 20 x 20 nautical miles and 3,000 feet in height simultaneously. The presence of several aircraft in one cell at the same time generates complexity, especially if they have different headings or flight phases. Each interaction is counted from each aircraft point-of-view; therefore, a cell with 2 aircraft will have a total of 2 interactions and a cell with 3 aircraft 6 interactions.

Traffic data within each cell are collected once per hour. So, for a one-day simulation there are 24 data sets for each cell.

Complexity indicators described below try to give a measure of the aircraft distribution in the airspace, how the aircraft are concentrated in certain parts of the airspace and how are they moving (climbing, descending or cruising).

With the objective of having a macroscopic view, the indicators focus on potential interactions between flows of aircraft during one-hour periods instead of actual interactions. This means that all potential interactions are taken into account, even if the aircraft were not simultaneously present at the same time in the cell.

2.5.5.1. Adjusted density

Adjusted density is a measure of the amount of traffic that exists within a given unit of volume over a given unit of time. It is defined as the quotient between the total duration of interactions in the cell and the total flight hours registered on the cell. Cells with no flights as they contain no interactions and no flight hours do not add anything to the calculation.

$$Adjusted\ Density = \frac{Total\ duration\ of\ interactions}{Total\ flight\ hours} \tag{2.2}$$

As each aircraft may have passed through the cell at any time during the hour, the duration of interactions between a pair of aircraft is defined as the product of the durations of both aircraft in the cell. The total duration of interactions is calculated as the sum of the duration of interaction of each pair of aircraft.

The total flight hours are the sum of the flight duration all the aircraft crossing the cell during the hour period.

2.5.5.2. Structural index

Vertical interactions (VDIF) take into account aircraft who are present in the same cell in different flight phases, climbing, cruising or descending. Only flights which vertical speed less than 500 ft per minute are considered cruising. Horizontal interactions (HDIF) include aircraft which difference between headings is greater than 20º. Finally speed interactions (SDIF) considers pair of aircraft which difference between speeds is greater than 35 kt.

The VDIF, HDIF and SDIF indicators are computed in a similar way as adjusted density.

$$VDIF = \frac{Total\ duration\ of\ vertical\ interactions}{Total\ flight\ hours} \tag{2.3}$$

$$HDIF = \frac{Total\ duration\ of\ horizontal\ interactions}{Total\ flight\ hours} \tag{2.4}$$

$$SDIF = \frac{Total\ duration\ of\ speed\ interactions}{Total\ flight\ hours} \tag{2.5}$$

For each dimension, relative indicators have been proposed (see Eqn. 3.6, 3.7 and 3.8). These values can also be interpreted as the percentage of interactions which are vertical, horizontal or due to speed differences:

$$Rel_{VDIF} = \frac{VDIF}{Adjusted\ density} \tag{2.6}$$

$$Rel_{HDIF} = \frac{HDIF}{Adjusted\ density} \tag{2.7}$$

$$Rel_{SDIF} = \frac{SDIF}{Adjusted\ density} \tag{2.8}$$

The structural index represents the structure of the traffic flows and is obtained as:

$$Structural\ Index = Rel_{VDIF} + Rel_{HDIF} + Rel_{SDIF} \tag{2.9}$$

2.5.5.3. Complexity score

Combining both aspects that affect complexity, the traffic volume and the structure of the traffic flows, the final complexity score can be obtained as:

$$Complexity\ score = Adjusted\ density \cdot Structural\ index \tag{2.10}$$

Higher values of complexity score mean a complex airspace. For air traffic controllers lower values will be beneficial.

CHAPTER 3. RESULTS OF NEFRA SCENARIO

This chapter presents all the results from this Project corresponding to the first scenario where NEFRA is evaluated.

3.1. Saved distance and emissions

Route length is an important indicator which provides a broad analysis of the route extension. This results on economic and environmental benefits for all of the airspace users.

Fig. 3.1 shows the results in terms of distance savings for each day. Recall that saved distance is the difference between the initial traffic distance for each traffic sample and the free route one. For all 21 traffic samples presented in section 2.2 free route simulations determine that airlines can save a considerable distance flying inside NEFRA. This distance reduction brings lots of benefits for airlines, regulatory organizations and airplane manufacturers in terms of reductions in greenhouse gas emissions, fuel consumption and the resultant economic impact.

As it can be seen in Fig. 3.1, for all three years distance savings are achieved. Values range from 3012 NM in the worst case to 5681 NM in the best case. Notice that in 2018 NEFRA free route was available but there were still airways. This is why distance savings are reduced respect 2012 traffic sample where the only way of flying was using airways. As traffic increases, approximately 20% in 2024, absolute distance savings also increase; this is why the highest values are found this year.

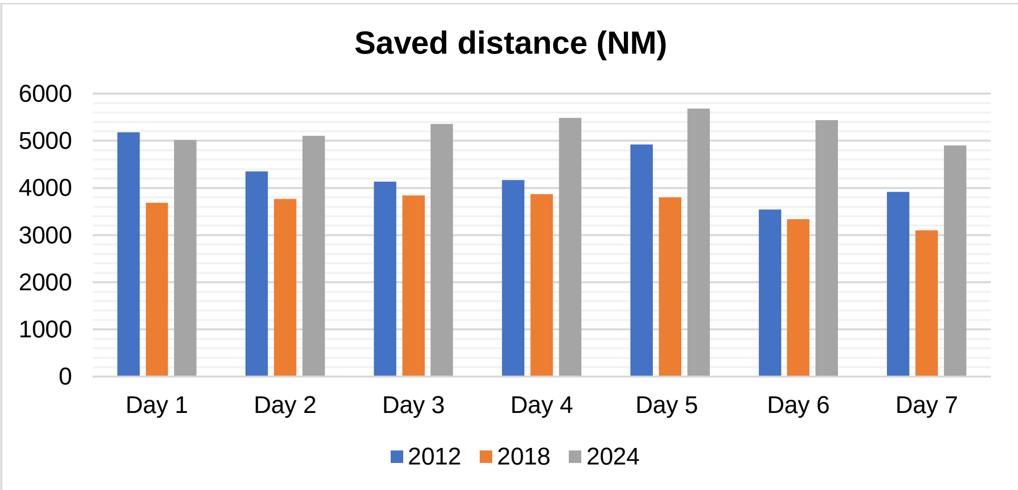


Fig. 3.1 Saved distance

Additionally, Fig. 3.2 shows the percentage of the saved distance respect the initial route length. For each day values range from 0.06% and 0.10% in years

2018 and 2024. Higher values appear in year 2012 reaching almost 0.16% because as mentioned before no route have been flown in free route airspace. Notice that if initial 2024 flight trajectories were free route trajectories the resultant free route savings would be 0 and the relative savings 0%.

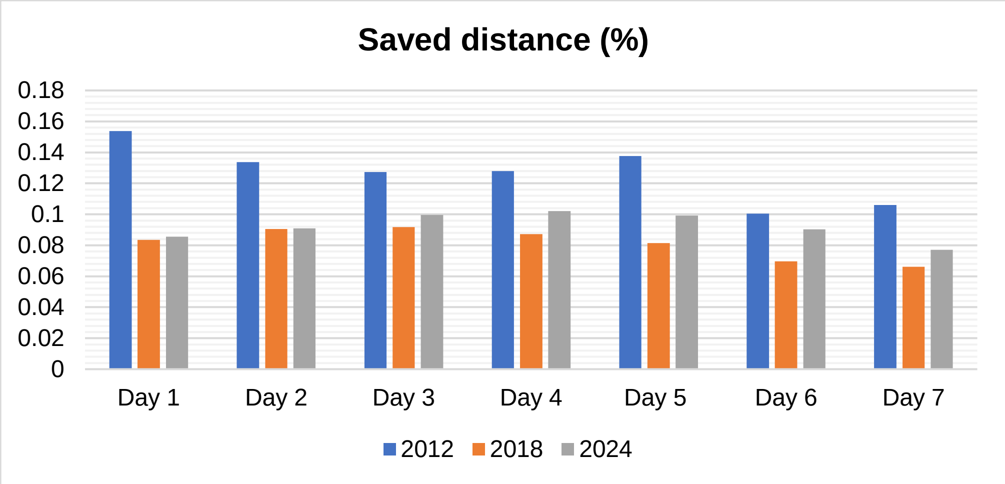


Fig. 3.2 Saved distance (%)

Carbon dioxide, CO_2, and water vapour (H_2O) are easily the most abundant products of jet fuel combustion (emission indices for CO_2 and H_2O are 3.15 kg/kg fuel burned and 1.26 kg/kg fuel, respectively) [24]. Considering the relation 1NM = 5.916 Kg fuel burned during cruise [25] and the fuel ton price of 689 € according to IATA fuel monitor (May 2019) [26] distance savings can be interpreted. Only in NEFRA in the year 2024 an average of 98.4 and 39.7 tons of CO_2 and H_2O can be saved per day. Benefits for airlines can ascend to 21.5 thousand Euros per day.

3.2. Route efficiency

Fig. 3.3 shows the results obtained when route efficiency is calculated. In this case values of the evaluated weeks have been averaged. Related with the results presented previously, as fight distance decreases route efficiency increases when free route is simulated. As a result, free route trajectories approximate to the idea of optimal trajectories.

Not considering wind conditions and vertical profile, the most efficient route (100%) will be the route following the great circle distance. Values presented in figure 4.3 show an average increment of flight efficiency of 0.10% reaching in the best case 95.37% of route efficiency in year 2024. This 4.63% needed to reach 100% are inefficiencies traduced to economic losses for airlines corresponding to longer distances. Notice that route efficiency and route distance are obtained from the full route from origin to destination. Considering only the free route area efficiencies would reach 100%.

Figure 3.3 also shows that trajectories are being more efficient while the years go by. In 2012 initial trajectories had an efficiency of 94.85% while in 2018 increased reaching 95.22% due to the implementation of NEFRA.

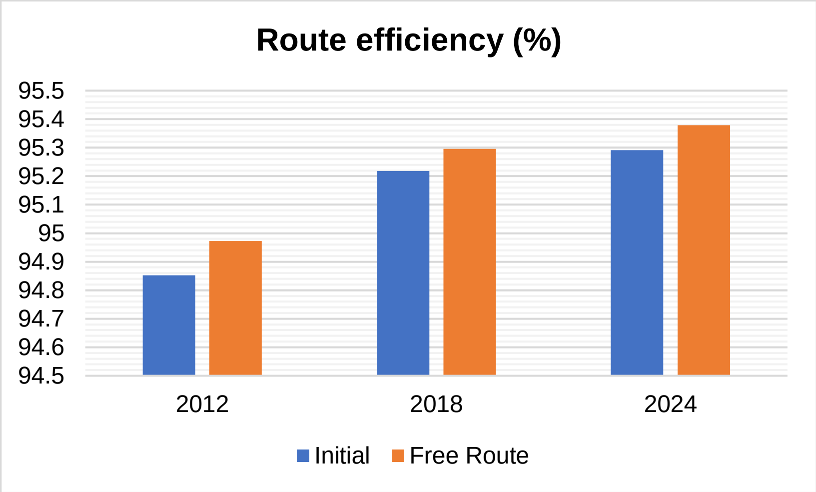


Fig. 3.3 Route efficiency

3.3. Flight Time

One of the benefits observed is the reduction of flight distance by allowing more direct routes. These savings are very related with the flight time. Fig. 3.4 shows the results when free route trajectories are simulated. As it can be seen, for all three traffic samples results determines that airlines can save time flying inside NEFRA.

In general, time savings present variability according the day and the traffic sample. Values range from 52 hours in 2012 traffic sample to 166 hours in 2024. Taking into account the number of aircraft crossing NEFRA in each traffic sample, for each day, each flight can save an average of 1 minute 48 seconds in 2024.

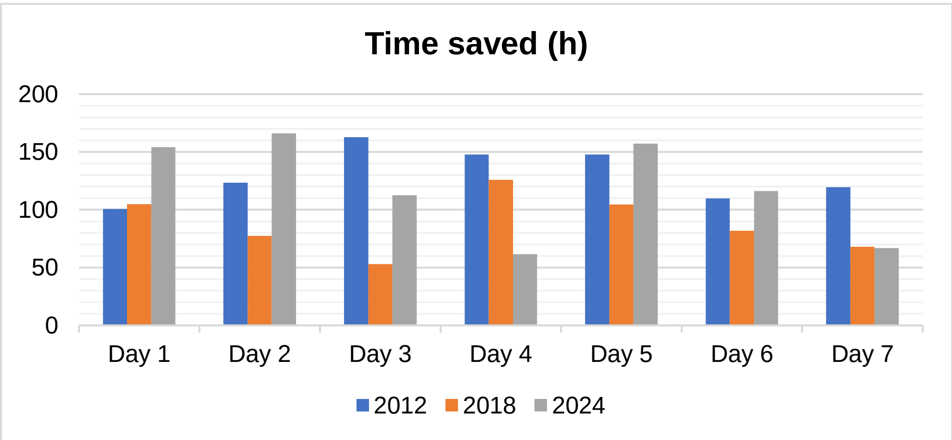


Fig. 3.4 Time saved

In a similar way, Fig. 3.5 shows the percentage of the time saved respect the initial route time. For each day values range from 0.46% and 2% in years 2024 and 2012 respectively. Higher values appear in year 2012 as in the case before.

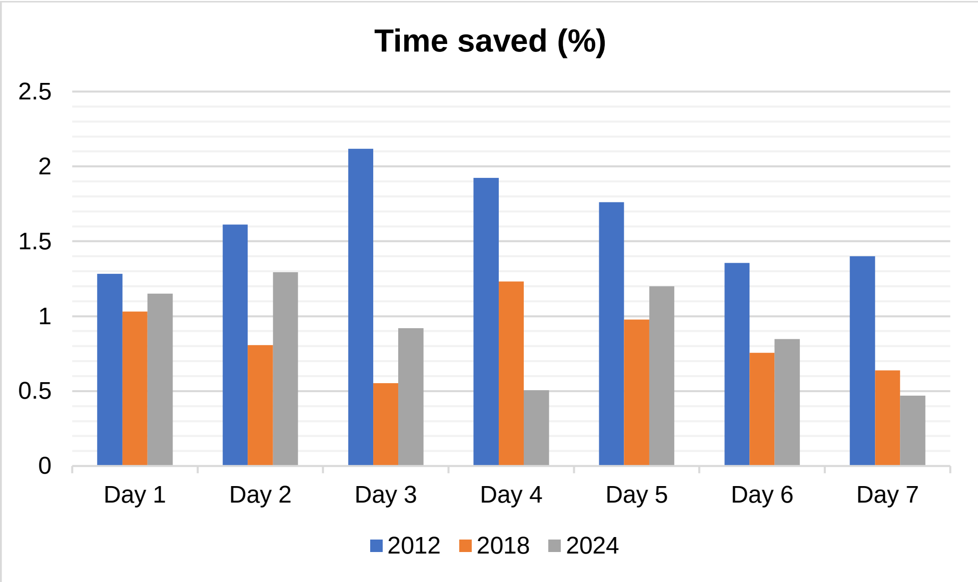


Fig. 3.5 Time saved (%)

3.4. Aircraft conflicts

Conflicts are accounted for flights which routes have a minimum distance of 5NM in horizontal and 1000ft in vertical. This, in fact, doesn't mean that a collision will occur but by safety reasons and the proximity they are located, air traffic controllers will have to separate it.

Table 3.1 shows the number of separation losses in each traffic sample for all days both initially and once simulated the free route trajectories.

Initially, the number of separation losses for the same year is very similar, in 2012 an average of 220 separation losses were produced. As air traffic has increased during the years the number or separation losses in the same area has also increased, reaching an average of 276 in 2018 and 448 in 2024.

Once trajectories have been free routed, considerable differences can be observed. In each traffic sample the number of separation losses has been decreased with respect to initial trajectories. This is probably due to the dispersion of the traffic over the airspace when free route is applied. Initial traffic, on the contrary, is accumulated in the airspace and aircraft tends to fly in the same portion of airspace.

Table 3.1 Number of separation losses

	2012		2018		2024	
	Initial	Free Route	initial	Free Route	initial	Free Route
Monday	232.9	220.7	287.2	277.0	500.6	388.8
Tuesday	204.7	196.4	284.8	274.3	463.5	376.5
Wednesday	259.0	223.0	277.7	249.8	446.7	364.2
Thursday	224.3	208.9	274.0	259.0	430.4	350.4
Friday	242.6	237.2	298.9	275.6	444.4	382.5
Saturday	170.8	177.7	235.8	215.1	459.9	377.0
Sunday	208.5	195.5	277	246.9	396.8	334.9

The difference between simulated potential conflicts and initial potential conflicts can be better observed in Fig. 3.6. The biggest difference is produced in 2024 reaching 111 conflicts saved.

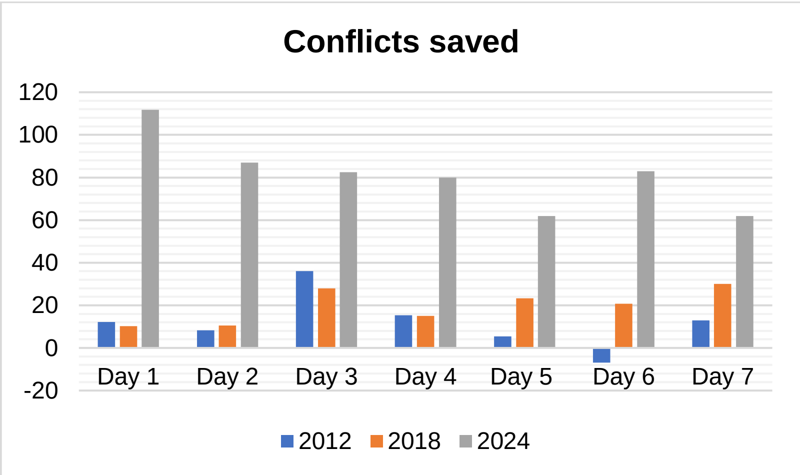


Fig. 3.6 Conflicts saved

With these results one can conclude that, as air traffic increases, free route is a good way to reduce the number of conflicts and the potentially airspace controller's workload.

3.4.1. Duration of the separation losses

Additionally, in Fig. 3.7, it is presented the duration of the separation losses for each day in a box-plot diagram for 2012 and 2018 traffic samples (2024 traffic sample follows the same behaviour than year 2018). This diagram contains:

- 'X': Arithmetic mean, it is what is traditionally known as average.
- Upper and lower limits: values above these limits are considered atypical.

- Median or middle quartile: marks the mid-point of the data and is shown by the line that divides the box into two parts. Half the values are greater than or equal to this value and half are less.
- Inter-quartile range: The middle "box" represents the middle 50% of scores for the group. The range of scores from lower to upper quartile is referred to as the inter-quartile range. The middle 50% of scores fall within the inter-quartile range.
- Upper and lower quartile: 75% of the scores fall below the upper quartile and 25% of scores fall below the lower quartile.

The duration of the separation losses observed has a high variance during the week but values are always below 20 seconds. When trajectories are simulated upper quartiles tend to decrease while lower quartiles remain the same. Upper limits have the same behaviour.

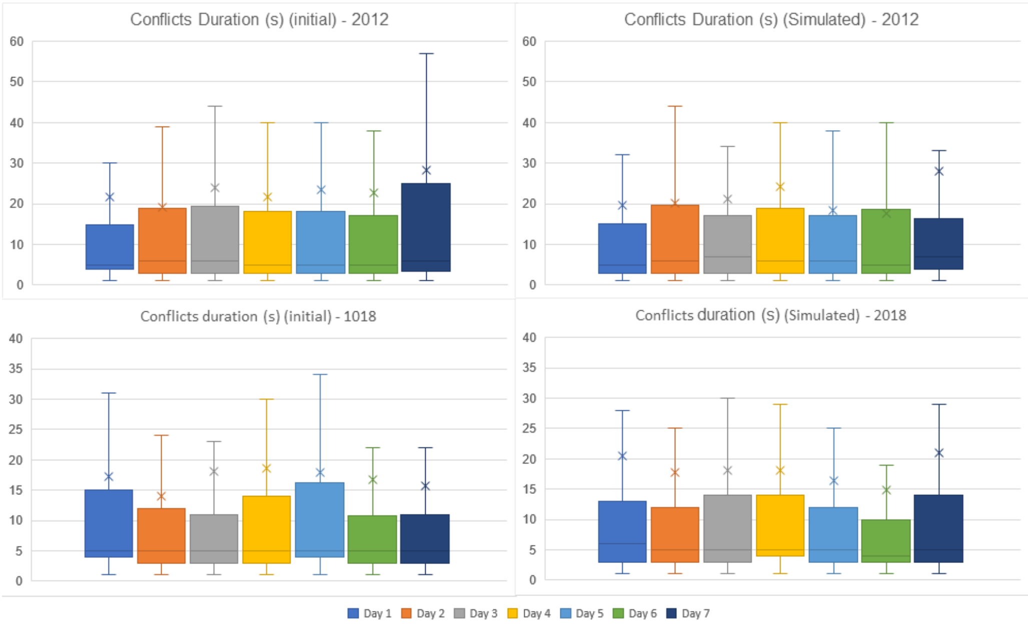


Fig. 3.7 Duration of the separation losses

3.4.2. Conflict types

Observing other parameters related with conflicts which are the conflict type, can be classified in different ways in order to study the benefits of free route airspace.

Fig. 3.8 classifies conflicts by the phase of the flight where are they flying. In both cases initial flights and simulated with free route trajectories. Green colour shows the ATC prefer conflict while yellow and red the most difficult to solve. An important detail that appears is that the percentage of conflicts between pair or aircraft flying in cruise is higher and, as a result, conflicts between pair of aircraft flying during cruise and doing evolutions decreases. This is an important benefit for aircraft controllers because detecting conflicts when aircraft are ascending or descending is more difficult to solve than cruise/cruise conflicts.

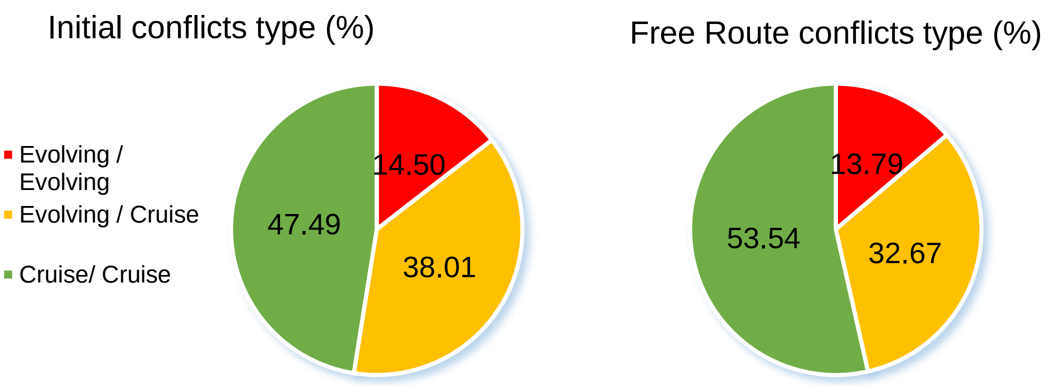


Fig. 3.8 Conflict types by phase of the flight

Looking at the horizontal movement of the traffic in Fig. 3.9, free route results show that the number of separation losses between aircraft flying parallel and in opposite directions have been reduced 5.75% and 0.85% respectively. Aircraft on crossing flows have been incremented by 6.56%, this situation is more complex to handle than aircraft in parallel or opposite flows. This increment in crossing flows is produced by the change of the route structure, air traffic initially was structured and when free route is simulated aircraft are free to fly in the direction they want.

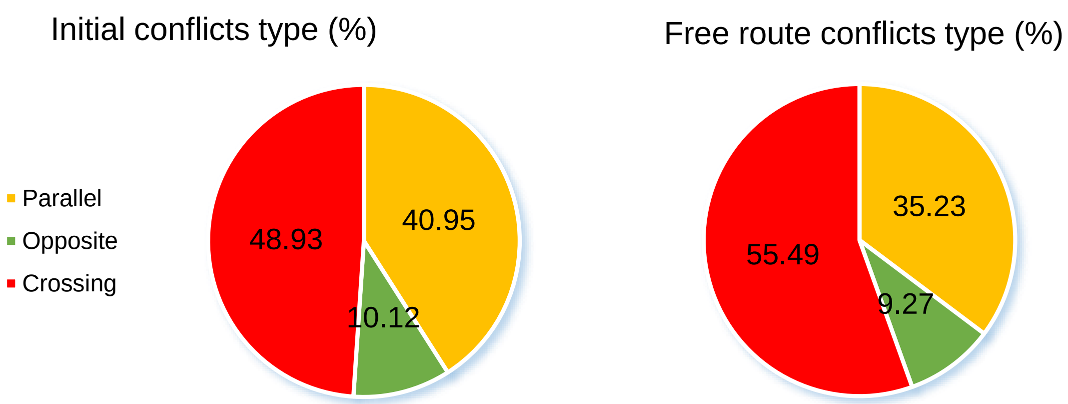


Fig. 3.9 Conflict type by aircraft direction

Finally, aggregating both situations mentioned above Fig. 3.10 is obtained. This figure also considers the three traffic samples averaged during the week. The biggest differences between initial and free route conflicts appear during cruise. In this phase of flight, while parallel and opposite conflicts are maintained, “crossing” situations increases by 6.72%. These situations shall be easily managed by controllers changing aircraft velocities avoiding managing headings that can generate more conflicts. Additionally, as mentioned before, all the conflicts relating aircraft doing vertical movements have been reduced.

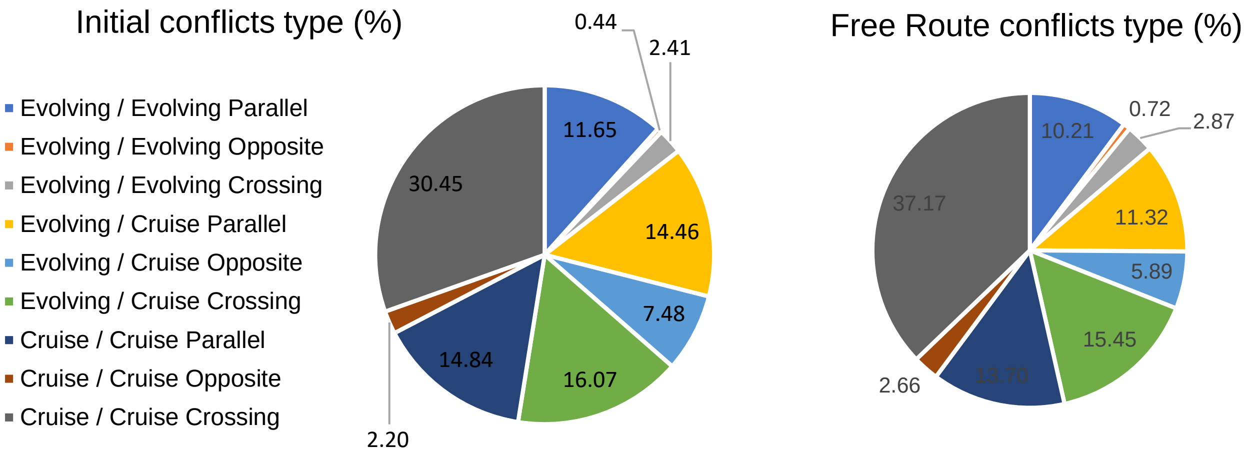
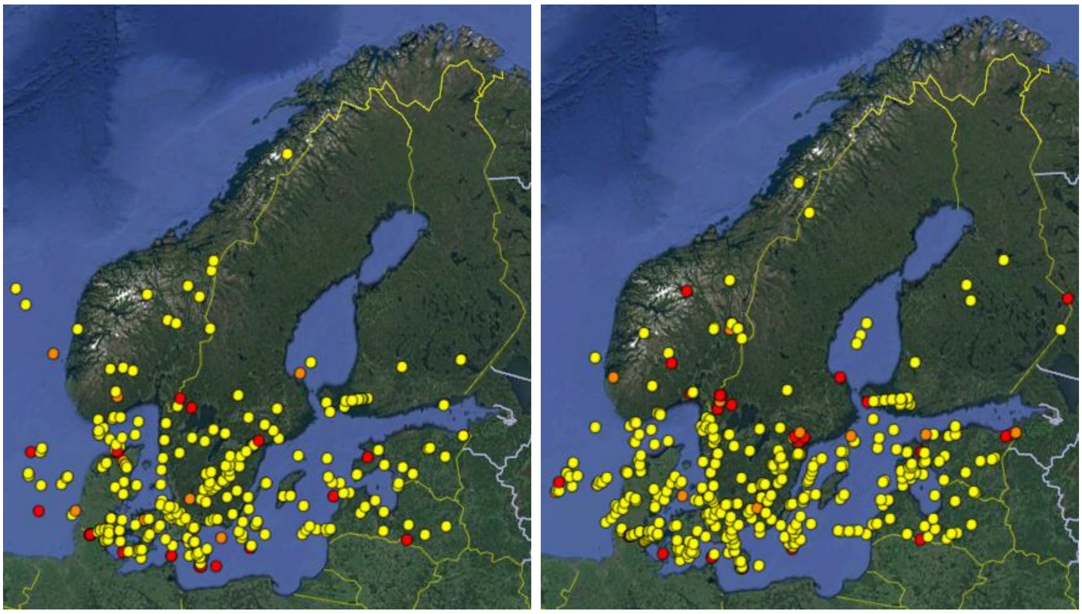


Fig. 3.10 Conflict types

3.4.3. Conflicts distribution

On the one hand, free routing produces very distributed conflicts where aircraft can emerge in any point of the airspace. These conflicts could be more difficult to handle due to the unexpected distribution of the conflicts. On the other hand, with structured airspace conflicts appear in airways and navigation points which are known. In the case of NEFRA, conflict distribution follows this argument. Fig. 3.11 shows the conflicts distribution for the 2024 traffic sample case. Separation losses have been plotted according to how dangerously they are:

- Red: Collision.
- Orange: separation loss < 600 ft.
- Yellow: separation loss > 600 ft.



a) Initial b) Free Route

Fig. 3.11 Conflicts distribution in NEFRA

3.5. Airspace complexity

3.5.1. Adjusted Density

Fig. 3.12 shows the adjusted density values (how traffic is dispersed in the airspace) for both scenarios initial and free route. Results have been obtained by averaging the results of the evaluated weeks. After doing the simulations adjusted density values decrease in years 2012 and 2024 while in 2018 remains constant when free route is simulated. The tendency of adjusted density values is to increase as the years go further form 0.065 in year 2012 to 0.090 interactions per flight hour in year 2024 initially. Free route values also increase from 0.063 to 0.089 in years 2012 and 2024 respectively. All values are lower than the European system value of 0.110 [23].

“The European system value is calculated using all the data from all the ANSPs or ACCs. These values assess complexity for the entire ECAC area as if it were a single ANSP or ACC” [23].

These results agree with the general expectation that with free route aircraft distribution through the airspace is wider and traffic doesn’t focus in airways or navigation points.

With the current airspace structure controllers have to handle more aircraft in a smaller volume of airspace than in free route airspace. This concentration in time and airspace explains the results obtained in section 3.4 where the number of conflicts decreases using free route airspace.

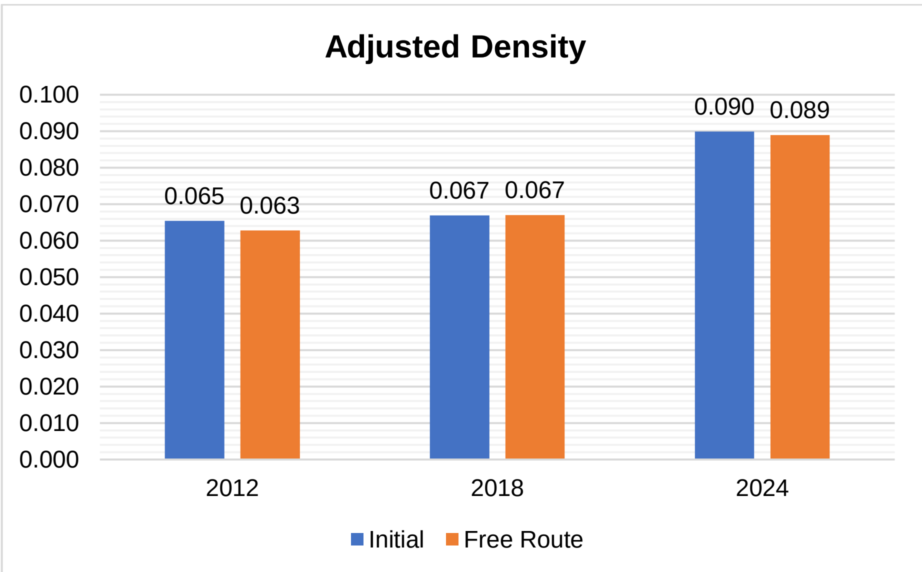


Fig. 3.12 Adjusted density

3.5.2. Structural index

This section shows the structural index components for both scenarios evaluated.

Fig. 3.13 shows the evolution of the vertical interactions (VDIF) in both scenarios, initial and free route for the three years. As in the case before, values of the corresponding weeks have been averaged. In the three years vertical interactions have decreased when free route has been simulated. This benefits controllers because the reduction in vertical interactions results in handling less traffic in “evolution” and solving fewer potential conflicts.

The tendency of the values is to increase but not significantly. Initial absolute values increase from 0.009 in 2012 to 0.010 in 2024 while Free route values increases from 0.007 in 2012 to 0.008 un 2024. All the values as in the last case are lower than the European system value of 0.028.

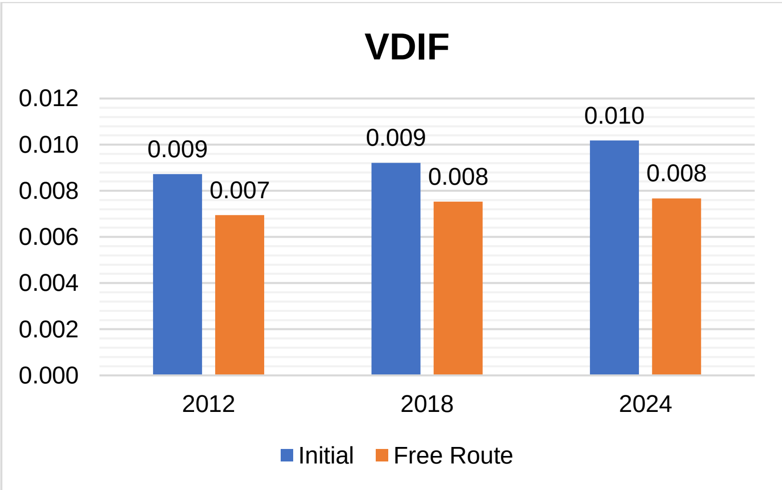


Fig. 3.13 Vertical Interactions

Horizontal interactions (see Fig. 3.14) take an opposite behaviour and increase when free route is simulated just as it did in the conflict analysis in section 3.4.2. Absolute values increase an average of 0.02 horizontal interaction per flight hour in the three years evaluated. The tendency is to increase as in the case before reaching in 2025 the maximum of 0.038 of horizontal interaction per flight hour being below the European system value of 0.046. Considering that vertical interactions are more difficult to detect this increase of horizontal interactions is not a drawback for controllers

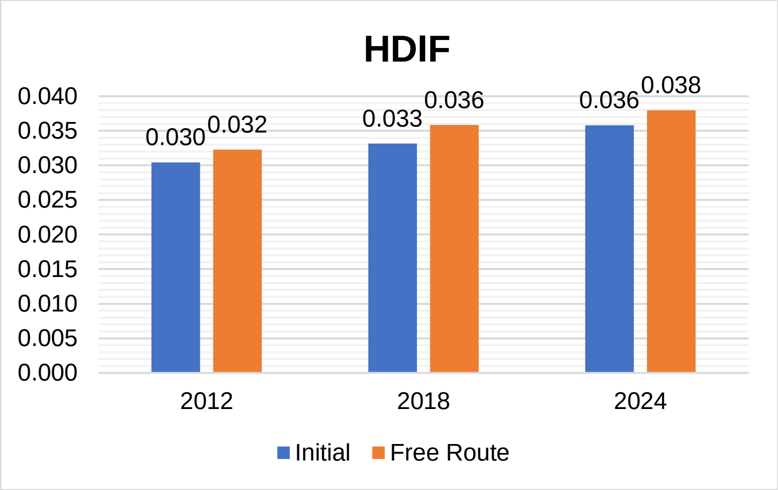


Fig. 3.14 Horizontal interactions

Finally, initial and free route SDIF show a different behaviour than the others structural index components (see Fig. 3.15). Initial indicator shows an increase of speed interactions from 0.006 in 2012 to 0.011 speed interaction per flight hour while free route remains approximately constant. All values are lower than the European system value of 0.025. The assumption is that a situation is less complex when aircraft have similar speeds as it happens in the studied scenario.

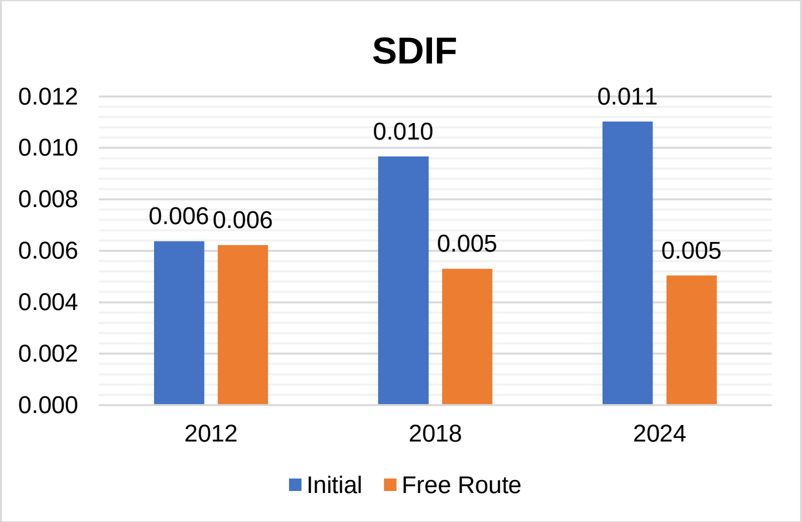


Fig. 3.15 Speed interactions

3.5.3. Complexity score

Fig. 3.16 shows the final complexity score (adjusted density x structural index). Figure shows that free route values of the complexity score have decreased respect initial values resulting beneficial. As air traffic increase, the complexity of the airspace also has to increase. The important detail is initial complexity increases from 0.046 in 2012 to 0.057 in 2024 and free route complexity increases but in a lower ratio, from 0.045 in 2012 to 0.050 in 2024. Therefore, free route is a good way to deal with the constant increase of air traffic in terms of airspace complexity.

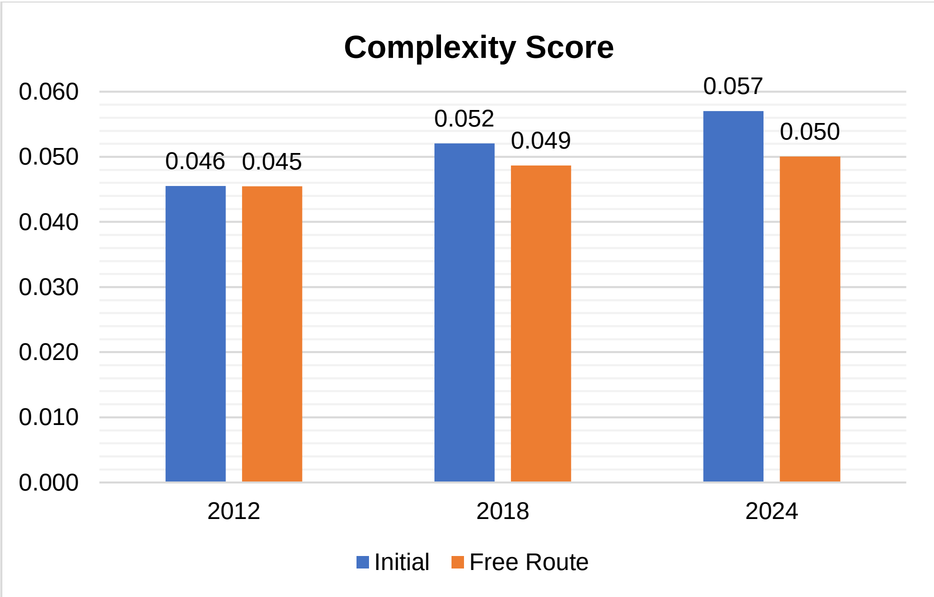


Fig. 3.16 Complexity score

CHAPTER 4. RESULTS EUROFRA SCENARIO

This chapter presents all the results from this Project corresponding to the second first scenario where EUROFRA is evaluated. This scenario pretends to evaluate Free Route Airspace in a futuristic point of view.

4.1. Route length and emissions

This first indicator Route provides a broad analysis of the route savings that a EUROFRA can generate.

Fig 4.1 shows the distance savings for each day in each traffic sample. For all 21 traffic samples free route simulations determines that airlines can save a considerable distance flying inside EUROFRA. For the same years, savings remains constant during the week because the number of flights is very similar. Nevertheless, comparing the three years can be deduced that the increment of air traffic is not proportional as the increment of distance savings. During 2012 savings are around 260,000 NM while in 2024 with an increment of approximately 20% of air traffic savings are doubled.

Only in EUROFRA in the year 2024 an average of 4,845 and 1,938 tons of CO_2 and H_2O can be saved per day. Benefits for airlines can ascend to 1.06 million Euros per day.

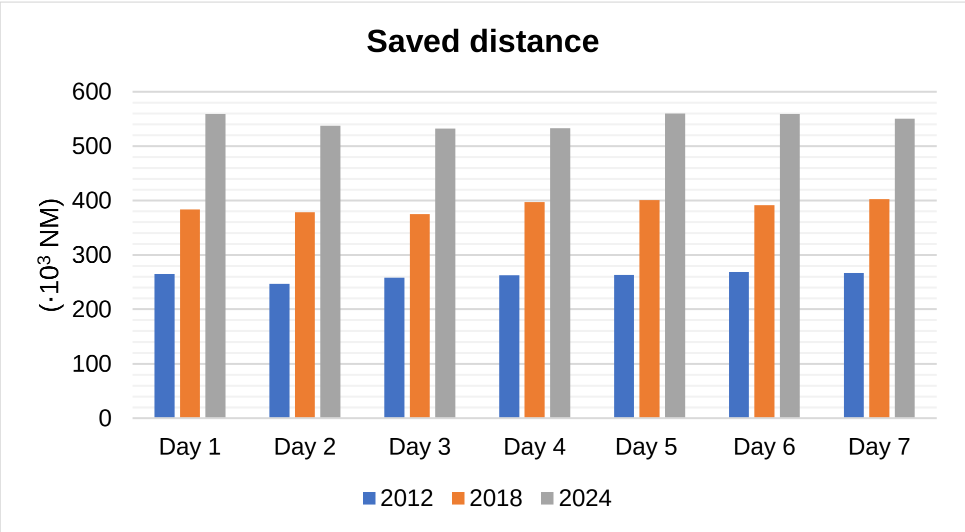


Fig. 4.1 Saved distance in EUROFRA

Additionally, Fig. 4.2 shows the percentage of the saved distance respect the initial route length. Values range from 1.06% in 2012 to 1.30% in 2024. Compared with NEFRA where higher values appeared in 2012, in EUROFRA higher values are in 2024.

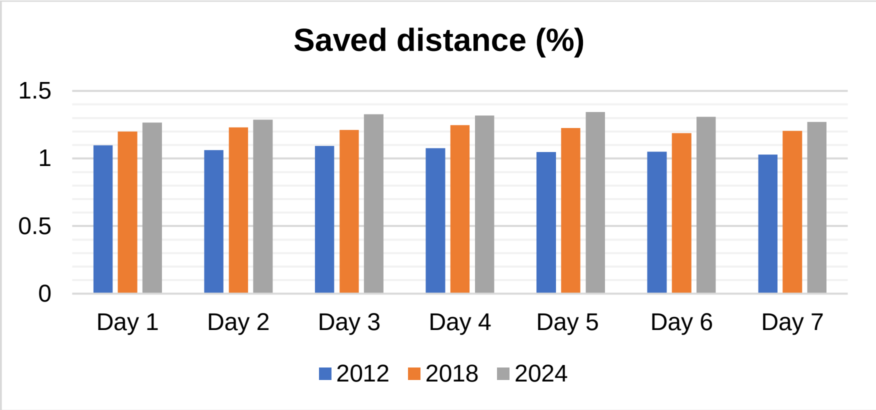


Fig. 4.2 Saved distance (%) in EUROFRA

4.2. Route efficiency

Fig. 4.3 shows the results obtained when route efficiency is calculated in EUROFRA. As in NEFRA scenario values of the weeks evaluated have been averaged. Free route trajectories approximate to the idea of optimal trajectories increasing the route efficiency in the three years.

Values presented in figure 4.3 show an average increment of flight efficiency of 0.13% reaching in the best case 95.49% of route efficiency in year 2012, higher than the last scenario evaluated.

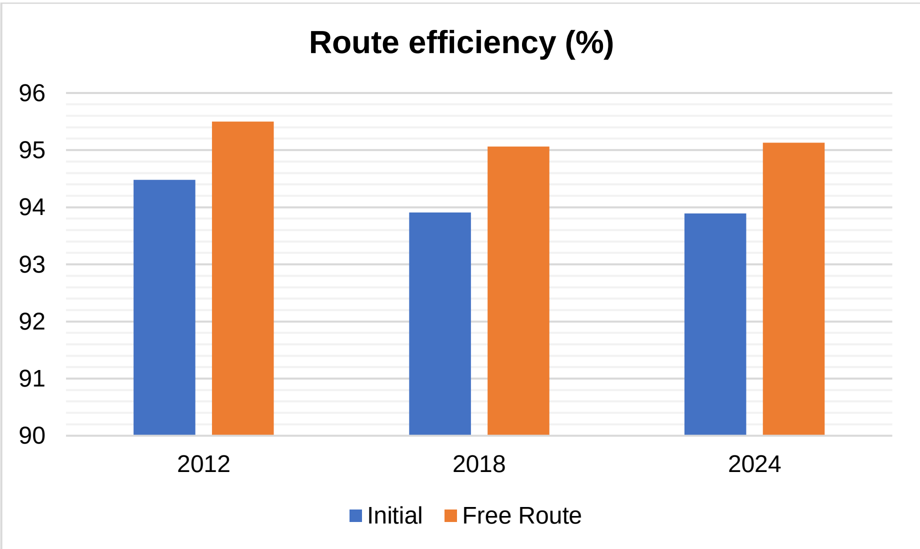


Fig. 4.3 Route efficiency in EUROFRA

4.3. Flight Time

Related with the results obtained before, Fig. 4.4 shows the results when free route trajectories are simulated. As it can be seen, for all three traffic samples results determines that airlines can save time flying inside EUROFRA.

In general, time savings present variability according the day and the traffic sample. Values range from 1,327 hours days in 2012 traffic sample to 2,792 hours of flight savings in 2024. This is traduced to 1 minute 18 seconds in 2012 and 1 minute 48 seconds per flight in 2024.

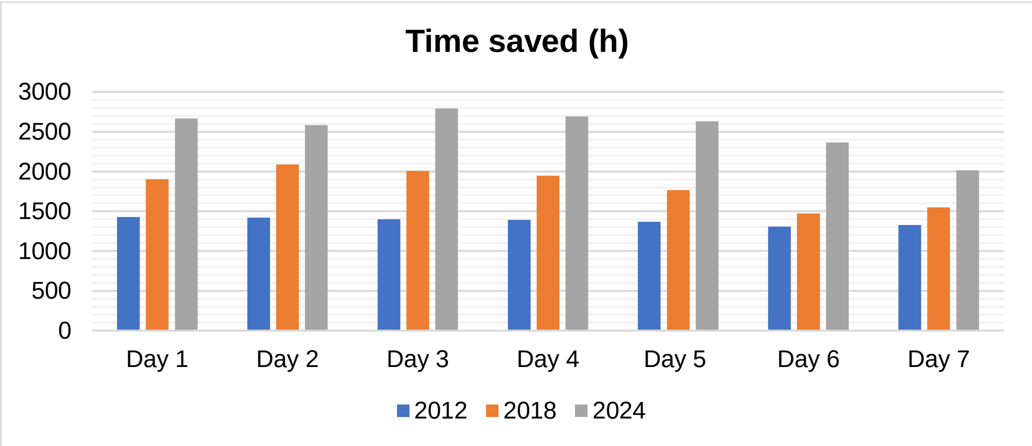


Fig. 4.4 Time saved in EUROFRA

In a similar way, Fig. 4.5 shows the percentage of the time saved respect the initial route time. For each day values range from 2% the minimum and 3% the maximum in years 2018 and 2024 respectively. In general, relative time savings present variability according the day and the year. No tendency can be seen.

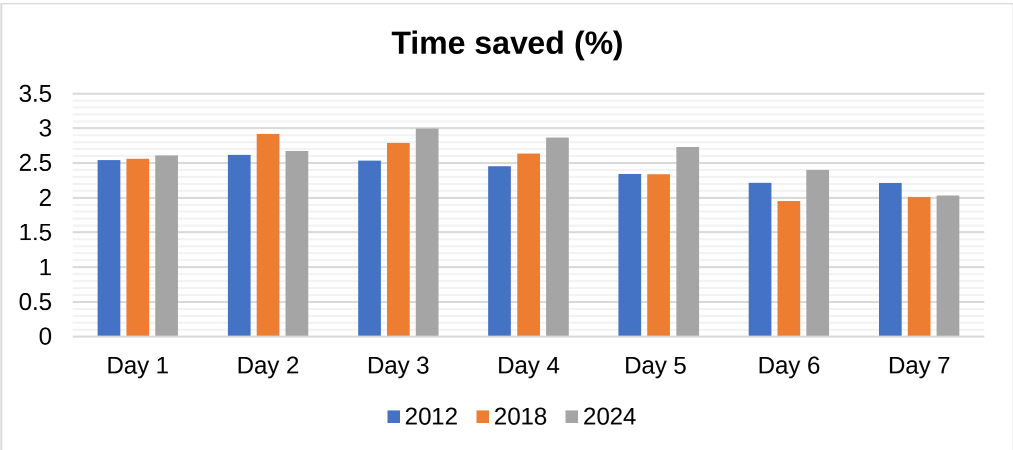


Fig. 4.5 Time saved (%) in EUROFRA

4.4. Aircraft conflicts

In this scenario, as in the case before, conflicts are accounted for flights with separation losses with other aircraft and, for safety reasons, air traffic controllers must separate it.

Table 4.1 shows the number of separation losses in each traffic sample for all days both initially and once simulated the free route trajectories. Initially, the number of separation losses for the same year is very similar, in 2012 an average of 6,987 separation losses were produced.

As air traffic has increases during the years the number or separation losses in the same area has also increased, reaching an average of 11,213 in 2018 and 18,737 in 2024.

Once trajectories have been free routed, considerable differences can be observed. In each traffic sample the number of separation losses has been decreased with respect to initial trajectories. In 2012 conflicts have been reduced 10.96% respect the initial number of conflicts while in 2018 and 2024 conflicts have been reduced 12.94% and 17.03% respectively.

Table 4.1 Number of separation losses in EUROFRA

	2012		**2018**		**2024**	
	Initial	Free Route	initial	Free Route	initial	Free Route
Monday	7,040	5,992	11,201	9,730	20,259	17,129
Tuesday	6,372	5,638	10,458	9,082	18,470	15,393
Wednesday	6,791	5,976	10,564	8,960	17,239	14,282
Thursday	6,746	6,034	11,189	9,654	17,410	14,128
Friday	7,244	6,538	11,635	9,998	18,686	15,180
Saturday	7,415	6,824	11,720	10,522	19,332	15,851
Sunday	7,306	6,548	11,731	10,399	19,764	16,850

The difference between simulated potential conflicts and initial potential conflicts can be better observed in Fig. 4.6. The biggest difference is produced in 2024 reaching 3,500 conflicts saved.

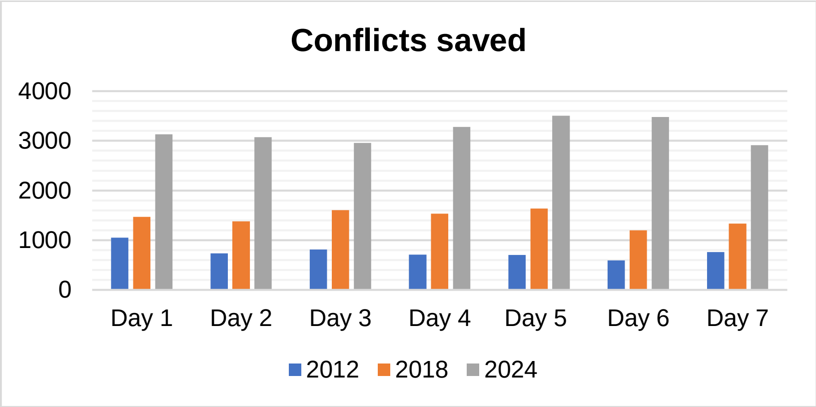


Fig. 4.6 Conflicts saved in EUROFRA

4.4.1. Duration of the separation losses

The duration of the separation losses observed has a high variance during the week but values are always below 20 seconds initially in the three years evaluated. When trajectories are simulated upper quartiles decrease significantly compared with NEFRA. For all three years upper quartiles reduces to the half reaching in the worst case 11 seconds. Additionally, upper limits and average values have been reduced to approximately the half. Lower quartiles remain the same. This behaviour of the separation losses benefits controllers because as aircraft are less time in conflict, they are usually faster to solve, for example, changing some velocities.

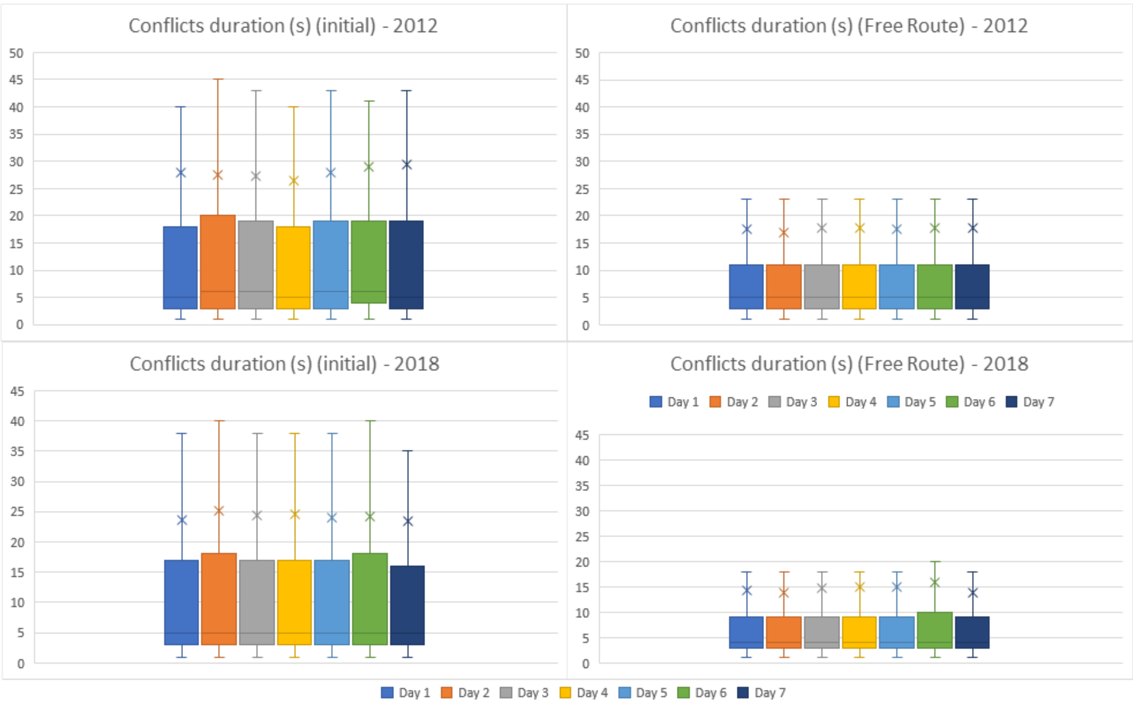


Fig. 4.7 Duration of the separation losses in EUROFRA

4.4.2. Conflict types

Fig. 4.8 classifies conflicts by the phase of the flight where are they flying. Green colour shows the ATC prefer conflict while yellow and red the most difficult to solve. As in NEFRA, the percentage of conflicts between pair or aircraft flying in cruise increases and, on the contrary, conflicts between pair of aircraft doing evolutions decreases. This result show that, in this Free Route Area, the conflict types by phase of flight match with the North European Free Route Area. Also, the percentages are very similar. As mentioned in the last scenario this situation benefits controllers because detecting conflicts when aircraft are ascending or descending is more difficult to solve than cruise/cruise conflicts.

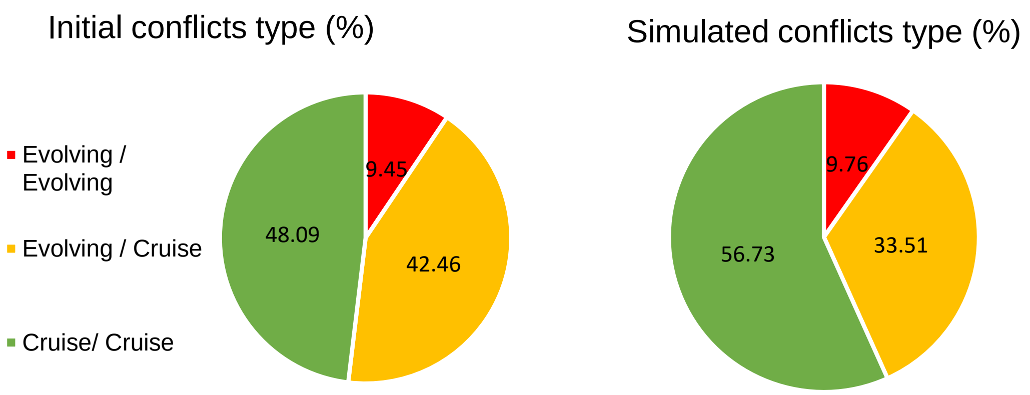


Fig. 4.8 Conflict types by phase of the flight in EUROFRA

Looking at the horizontal movement of the traffic in Fig. 3.9, free route results show that the number of separation losses between aircraft flying parallel and in opposite directions have been reduced 19.44% and 0.66% respectively. While in NEFRA aircraft on crossing flows increased by 6.56%, in EUROFRA increase 20.10% by the change of the route structure, resulting in a more complex situation.

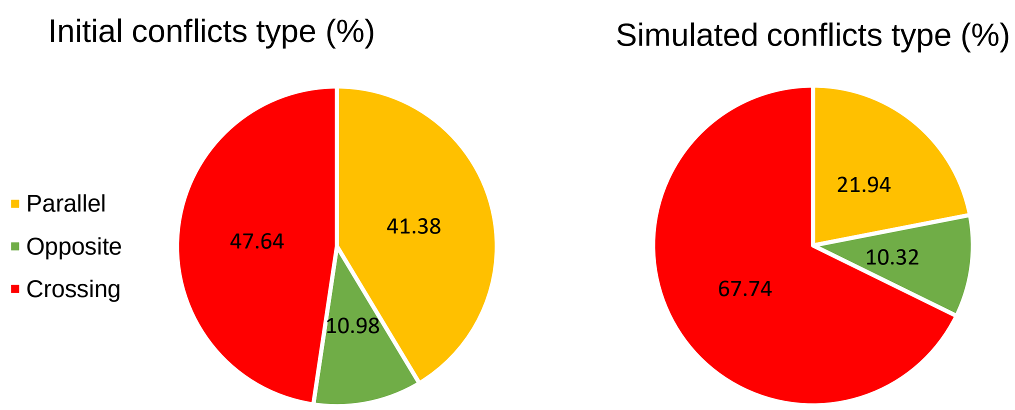


Fig. 4.9 Conflict type by aircraft direction in EUROFRA

Finally, aggregating both situations mentioned above Fig. 4.10 is obtained. The biggest differences, as in NEFRA scenario, between initial and free route conflicts appear during cruise. In this phase of flight, “crossing” situations increases by 16.72%, 10% more than in NEFRA. This increment in cruise conflicts are traduced to a reduction of conflicts relating aircraft doing vertical movements which is beneficial.

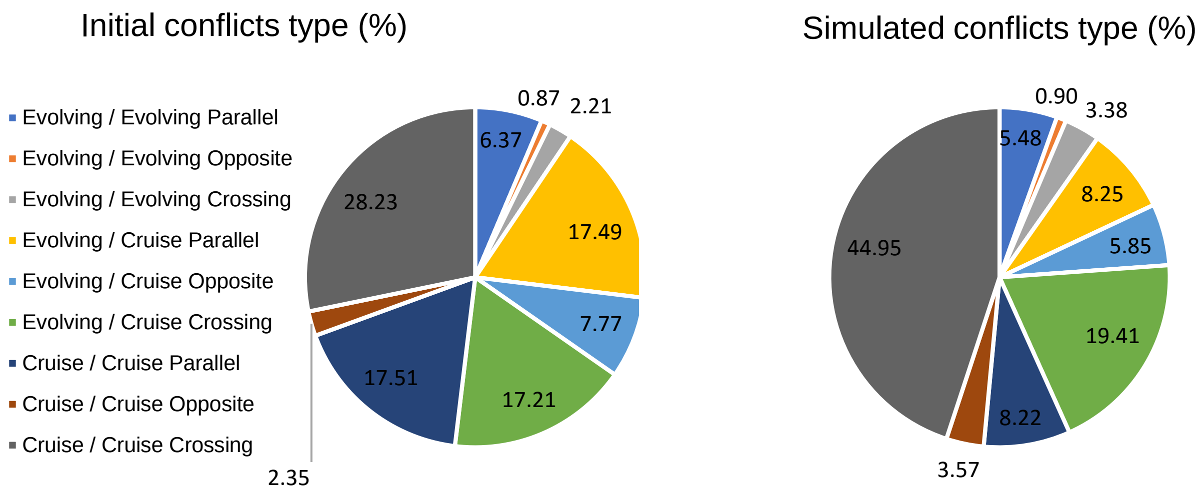


Fig. 4.10 Conflict types in EUROFRA

4.4.3. Conflicts distribution

Fig. 4.11 shows how conflicts are distributed with the current airspace configuration. Separation losses have been plotted according to how dangerously they are as in section 3.4.3.

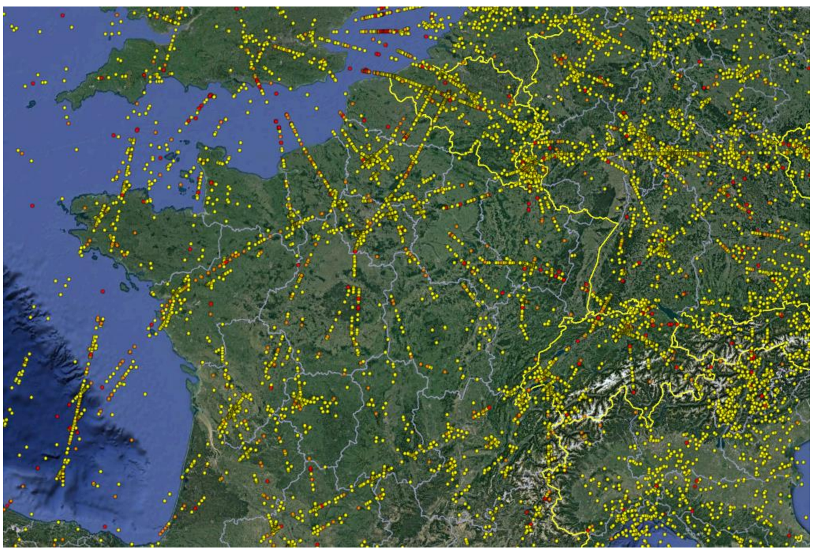


Fig. 4.11 Initial conflict distribution in the central of EUROFRA

As can be seen conflicts emerge in airways and navigation points which are known. This situation produces more dangerous conflicts than free route configurations. Recall that orange and red dots represent dangerous separation losses.

Fig. 4.12 represents the conflict distribution in EUROFRA. In this scenario there are less separation losses and yellow dots are the most abundant. However, free routing produces very distributed conflicts where aircraft can emerge in any point of the airspace and can be more difficult to handle.

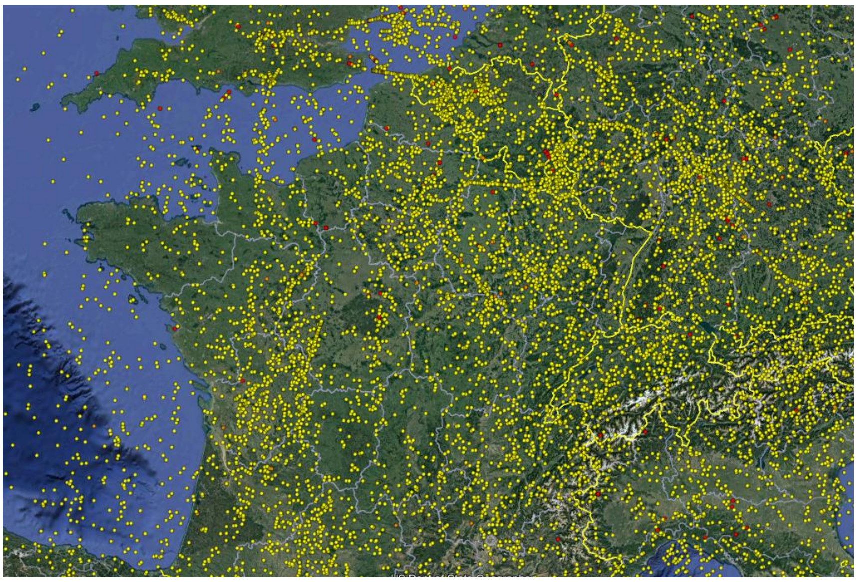


Fig. 4.12 Free Route conflict distribution in the central of EUROFRA

4.5. Airspace complexity

4.5.1. Adjusted Density

Fig. 4.13 shows how traffic is dispersed in EUROFRA for both scenarios initial and free route. Results have been obtained by averaging the results of the weeks of the three years evaluated. After doing the simulations adjusted density value decreases in the three years. Compared with NEFRA, in EUROFRA as the volume of airspace increases, differences between initial and free route are bigger. Also, EUROFRA includes the central part of EUROPE where is located is the highest density of air traffic.

The tendency of adjusted density values, as it happened in NEFRA, is to increase as the years go by form 0.148 in year 2012 to 0.252 interactions per flight hour in year 2024 initially. Free route values also increase from 0.110 to 0.189 in years 2012 and 2024 respectively.

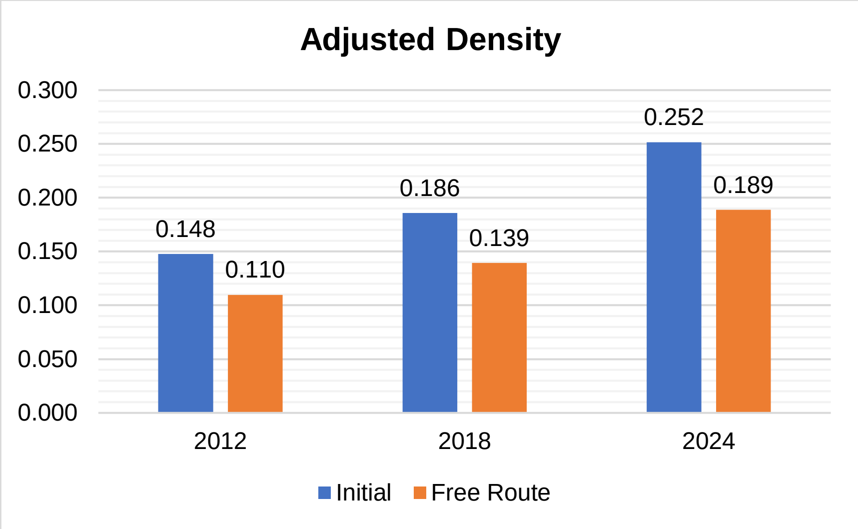


Fig. 4.13 Adjusted density in EUROFRA

4.5.2. Structural index

This section shows the structural index components in the EUROFRA scenario.

Fig. 4.14 shows the evolution of the vertical interactions (VDIF). In the three years, as in NEFRA, vertical interactions have decreased when free route has been simulated resulting beneficial for controllers.

The tendency of the values is to increase during the years. Initial absolute values increase from 0.020 in 2012 to 0.030 in 2024 while Free route values increases from 0.013 in 2012 to 0.018 un 2024.

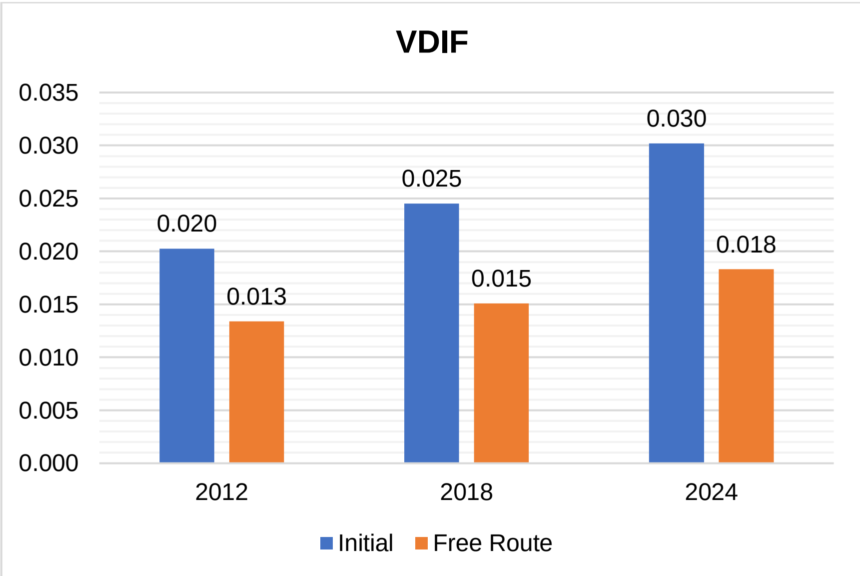


Fig. 4.14 Vertical Interactions in EUROFRA

Horizontal interactions (see Fig. 4.15) take an opposite behaviour and increase when free route is simulated just as it did in NEFRA.

The tendency is to increase as in the case before reaching in 2025 the maximum of 0.109 of horizontal interaction per flight hour. Considering that vertical interactions are more difficult to detect this increase of horizontal interactions is not a drawback for controllers.

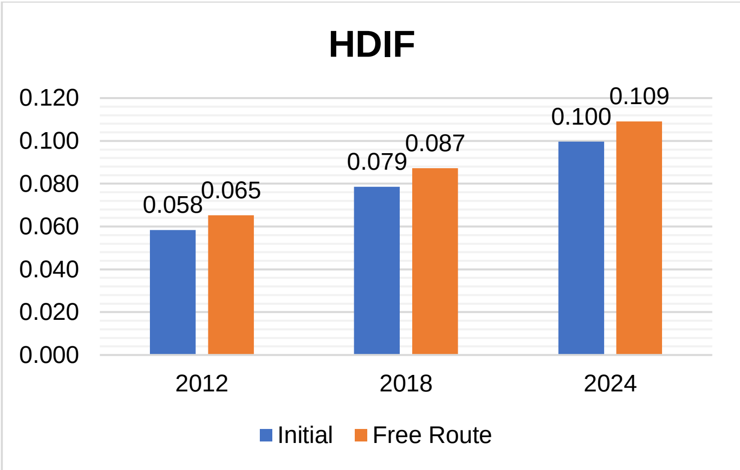


Fig. 4.15 Horizontal interactions in EUROFRA

The last structural index component is shown in Fig. 4.16. This indicator has the same behaviour as in NEFRA. While the initial values increase as the years go by, free route values remain approximately constant. Initial indicator shows an increase of speed interactions from 0.011 in 2012 to 0.019 speed interaction per flight hour while free route remains approximately constant in 0.009 speed interaction per flight hour.

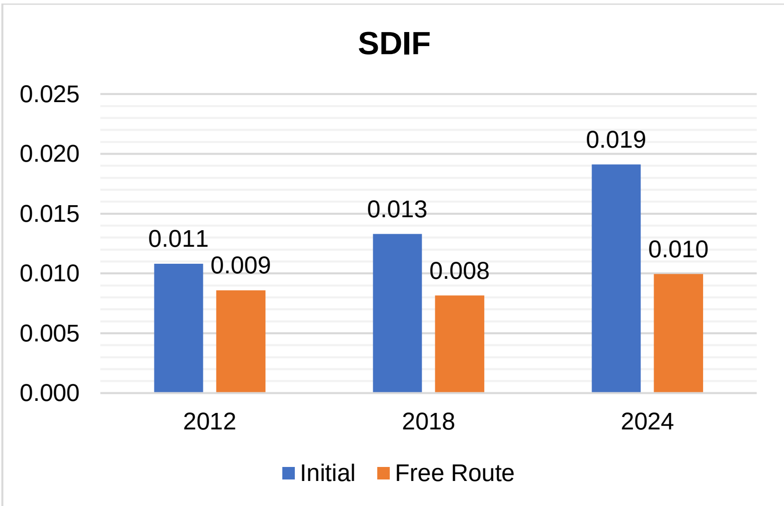


Fig. 4.16 Speed interactions in EUROFRA

4.5.3. Complexity score

Fig. 4.17 shows the final complexity. Figure shows EUROFA is less complex than the actual airspace configuration. As air traffic increase, the complexity of the airspace also increases. Initial complexity increases from 0.090 in 2012 to 0.149 in 2024 and free route complexity increases but in a lower ratio, from 0.087 in 2012 to 0.137 in 2024. These values are similar as the Italian airspace complexity which is 0.120, far from the complex airspace which is Belgium with 0.220.

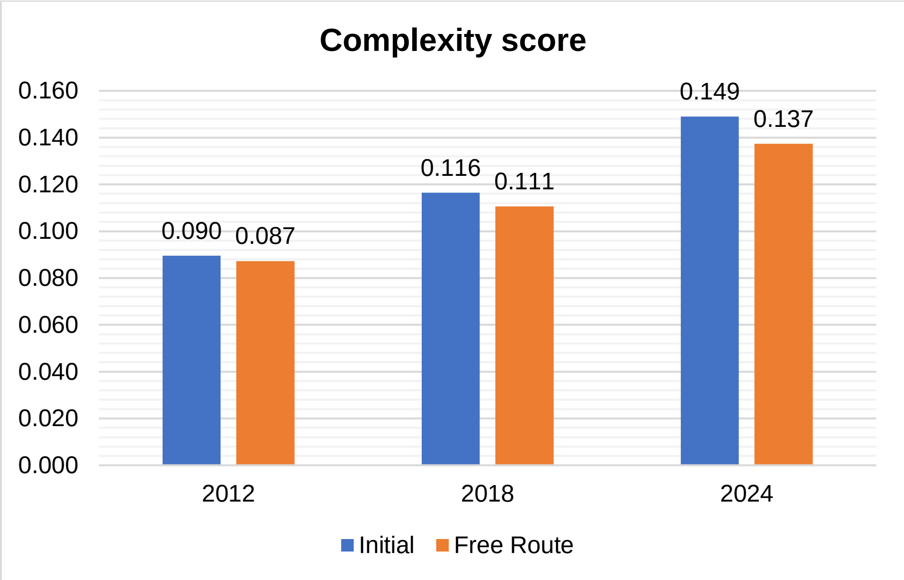


Fig. 4.17 Complexity score in EUROFRA

CHAPTER 5. CONCLUSIONS

The main goal of this Project was to study the benefits of the deployment of Free Route Areas in EUROPE. To make it possible, some parameters such as flight distance or complexity have been evaluated in different scenarios.

The theoretical review has evidenced that demand of air traffic is growing every year. In 2020 EUROCONTROL forecast to reach 11.65 million flights which implies in more delays, flight cancellation and CO_2 emissions increase. This situation implies the need of continuous improvement of European ATM which includes the progressive implementation on Free Route Areas allowing users to travel by direct trajectories between entry and exit points.

The simulation done by NEST estimates that almost 6 thousand NM can be saved only flying in NEFRA in year 2024 per day flying more efficient. This implies a daily savings of almost 40 tons of CO_2 and approximately 21 thousand euros. These advantages can be enhanced flying in EUROFRA where savings achieve 260 thousand NM and 2 thousand tons of greenhouse emissions.

From the ATS and ANSP point of view, results related with conflicts and complexity conclude that safety is maintained in both scenarios. On the one hand, air traffic controllers have to handle more dispersed traffic which difficult the detection of potential conflicts. On the other hand, they have to solve less conflicts related with vertical movement. Also, for all 21 traffic samples the total number of conflicts have been reduced. This validates the last indicator where complexity decreases in Free Route areas.

Finally, conclude that future works related with Free Route should be focused on an improvement of the “Free route process” by NEST allowing the simulation of entire trajectories including TMA procedures. Also, and not less important, works should be focused on the challenging problem of renovating the sectorization of the airspace to be able to assign air traffic controllers according to the expectations of the traffic demand, especially in futuristic scenarios as EUROFRA.

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